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Citrus Fruit Products[1]

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INTRODUCTION

Many agricultural industries are confronted with the problem of the satisfactory disposal of their surplus and cull material. Often the profit on the whole crop depends on the handling of this part of it, for if even a small percentage of the surplus is sold in competition with the fancy and choice grades, the prices received for these better grades may be so lowered as to render the entire transaction unprofitable. The disposal of waste material nearly always entails some cost, and this must be taken into consideration in deciding upon the economic value of the byproduct. Usually the surplus raw material can be used as fertilizer, or it can be fed to stock, but these uses are a last resort, for nearly always more profitable methods of disposal can be worked out.

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[1] Supersedes Department Circular 232, By-products from Citrus Fruits.

For many years citrus growers have faced these problems, and have had no small measure of success in solving them (*33*). Naturally not a few commercial experiments, as well as many carried out in the laboratory, result in failure. Further, it is always more or less difficult to adapt laboratory methods to commercial production. Some growers have been discouraged at times by these difficulties, but the majority are steadfast in their belief that citrus-products manufacture is essential to profitable citrus-fruit growing. The principal benefit received by the growers from the manufacture of citrus products is in the removal of surplus and undesirable fruit from the market for packed fruit. The cooperatives engaged in the citrus-products business regard it as a part of their fresh-fruit marketing plan, and expect it to succeed only as part of that plan. With surpluses ranging from a few thousand tons one year to more than 100,000 tons the next year, cooperative citrus-products plants (fig. 1) seem to be the best possible means of stabilizing the fresh-fruit market. Even if growers

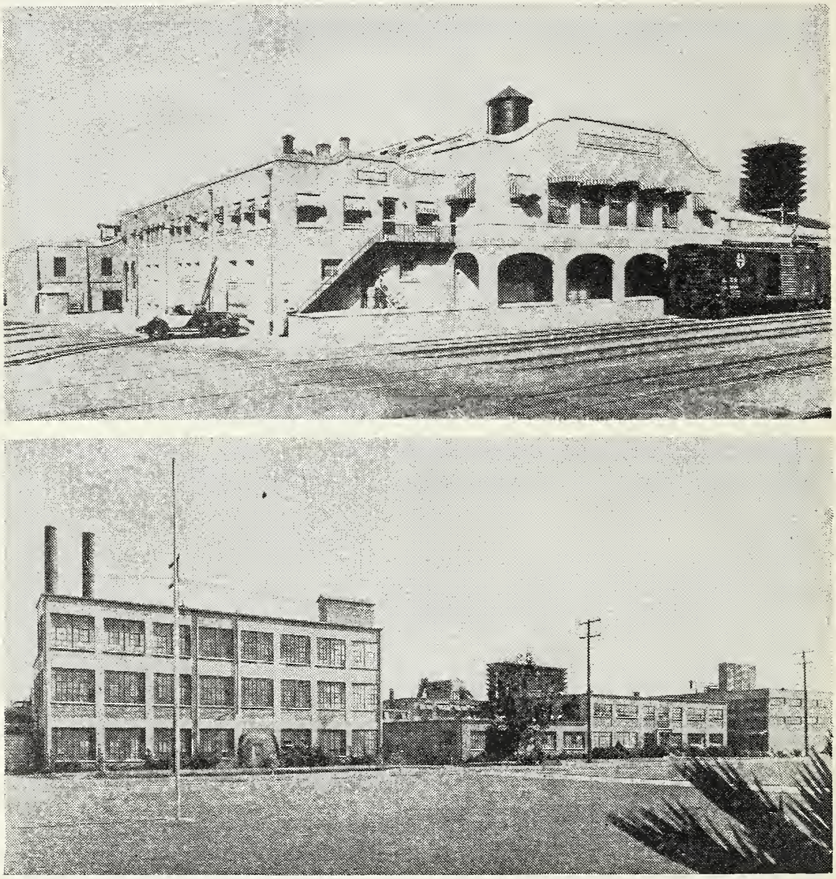

Figure 1.—California plants actively engaged in the manufacture of citrus products.

do not receive the entire cost of growing cull and surplus fruit, the plants may still be considered successful undertakings owing to their effect in upholding the price of fresh fruit.

The canning of grapefruit segments, grapefruit juice, and orange juice has been a distinct advance in this field, and has done much toward solving the problem of overproduction.

Naturally, business foresight is required for success in this field. Sources of supply as well as selling opportunities must be carefully studied. It must always be kept in mind that over a period of years, partial and at times complete crop failures are to be expected. At such times it is difficult for noncooperative enterprises to weather the storm of high prices and limited supply. Cooperatives are in a somewhat better position, because their members, if they have fruit, are better able, in view of the good prices they are receiving from the sale of their fresh fruit, to sustain losses from their byproducts plants.

In normal years, to the casual observer there seems to be a large quantity of fruit under the trees, but a careful check will reveal that the amount is so small that it is not worth picking up and hauling to a central point. As a rule, most of the fruit on the ground has dropped because of some physical defect, in which case it is seldom satisfactory material for processing.

The purpose of this circular is to describe the latest methods for the manufacture of citrus products. It is intended for general information. For more detailed information and a survey of the literature, the reader is referred to McNair (*45*)[2] and Matlack.[3]

The methods for byproduct manufacture brought together in this circular are the result of experimental work carried on by the United States Department of Agriculture. Technical aid is required in carrying out some of the operations, and in many cases local conditions will determine their economic value (*86, 89*).

STRUCTURE AND COMPOSITION OF CITRUS FRUITS

STRUCTURE

The byproducts of citrus fruits consist of peel, pulp, and with few exceptions, seeds.

The peel constitutes from one-fifth to three-fourths of the weight of the fruit. It is made up of the flavedo, or outer portion, containing the oil glands and the coloring matter, and the albedo, or white spongy inner layer. The albedo may be almost lacking in some fruits of the mandarin type and very abundant in some varieties of grapefruit and citron.

The pulp is contained in the segments, which together with the central axis constitute what is often called the rag. The pulp is made up of slender spindle-shape juice sacs, attached by hairlike stalks to the inner peripheral surface of the segments. In addition to the juice, these sacs contain small vesicles which secrete waxy substances (*23*).

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[2] Italic numbers in parentheses refer to Literature Cited, p. 42.

[3] MATLACK, M. B. BIBLIOGRAPHY OF THE CHEMISTRY OF THE GENUS CITRUS. U. S. Dept. Agr., Bur. Chem. and Soils Pub. 170 pp. 1932. [Mimeographed.]

The seeds are attached to the inner angle of the segments where they join the central axis. The number of seeds ranges from none in the Washington Navel oranges to more than 100 in some strains of seeded grapefruit.

Composition

The volatile oils contained in the outer cells of the peel are used for flavoring purposes and, to a less extent, in perfumes. They vary greatly in composition, but usually consist of 85 to 95 percent of the terpene, limonene; with 15 to 5 percent of aldehydes and esters (*55, 56, 58, 66*). The aldehydes and esters are largely responsible for the flavor and odor of the citrus oils.

The inner part of the peel, the albedo, consists of cellulose, hemicellulose, lignin, pectin, pentosans, sugars, glycosides, bitter substances, and mineral matter. The glycoside in oranges, lemons, and tangerines is hesperidin; that in the pomelo or grapefruit, naringin.

The pulp of citrus fruits is made up of soluble solids, in solution in the juice, and insoluble solids, consisting of segment and juice-cell walls. Insoluble solids vary in the different types, from 1 to 10 percent being present. In composition the pulp from which the juice has been extracted does not differ greatly from the albedo, containing cellulose, hemicellulose, pectin, pentosans, etc. Soluble solids are largely sugar or acid. In mature citrus fruits of the sweet edible types, the sugars constitute from 80 to 85 percent of the soluble material in the juice. In the acid types, citric acid may amount to more than 5 percent of the dissolved solids. The sugars are levulose, dextrose, and sucrose. The predominant acid is citric, but small quantities of malic acid have been reported. The nitrogenous matter is largely nonprotein. Stachydrine, arginine, choline, asparagine, cysteine, and lysine have been found in small quantities (*60*). Both ethyl alcohol and inositol are present.

As in most other fruits, more than 50 percent of the mineral constituents of orange pulp are potash salts, which are alkaline in reaction. About 20 percent of the ash is calcium salts, 10 percent is phosphates, and 5 percent is magnesium salts. Sulfur, sodium, silicon, and chlorine are present in smaller amounts, and the presence of iron, manganese, copper, zinc, boron, and iodine has also been reported. Arsenic is absent.

The juices of most citrus fruits are rich in vitamin C (*9, 61*), contain some vitamin A, and are fairly good sources of vitamins B and G (*22, 78*).

The seeds of citrus fruits contain a fixed oil that is quite different from the volatile oil in the peel. It consists of the glycerides of palmitic, stearic, oleic, linolic, and lignoceric acids (*36*), with some free acid and unsaponifiable matter. The seeds also contain protein, carbohydrates, fiber, and mineral matter, and are the only part of the fruit in which starch has been found.

PRESERVING CITRUS FRUIT JUICES

Orange and Grapefruit Juices

For many years, the satisfactory canning of orange juice remained an unsolved problem. Little by little the obscure causes of failure have been discovered and eliminated, and now there are satisfactory juices on the market (*50, 84*). To be satisfactory, canned orange juice must not only have a pleasing flavor, preferably as nearly as possible like that of the fresh juice, but it must retain this flavor after several months' storage at temperatures from 70° to 90° F. Some orange juices have a satisfactory flavor when first canned but do not retain it during storage. The flavor of grapefruit juice is not so easily affected by time and temperature as that of orange juice, and consequently this juice is easier to handle (*2*). Whenever possible, citrus juices should be stored at 60° or less. The quality of all juices deteriorates in proportion both to the temperature and the length of the storage period. It is an exceptional product that will retain its quality for more than a year at ordinary storage temperatures, that is, from 70° to 90°. On the other hand, properly prepared frozen juice when sealed in vacuum containers and kept at 0° will keep its fine quality for 2 years or more (*41*).

It is now recognized that one of the causes of former failures was the fact that the juice was not freed from air before heating it to destroy the organisms causing spoilage (*26*). Another factor was the temperature used in flash pasteurizing. For many years, the idea prevailed that the lowest temperature at which the spoilage organisms could be destroyed was the proper one to use. Better results are now obtained by using higher temperatures for shorter periods, and cooling the juice immediately (*38*).

As is the case with most food-manufacturing operations, the selection of the raw stock for the production of juice is of first importance. Immature and overripe fruit, fruit kept too long after picking, or that containing decayed material, should never be used. Canning the juice does not improve its quality, and the imperfections of the raw material are more noticeable in the canned product.

The cleanliness of the factory and surrounding premises is also extremely important. All surfaces coming in contact with juice should be sterilized with steam daily. If possible, floors and walls should be frequently steamed or washed down with a volatile antiseptic such as a chlorine solution.

The last juice going through the flash pasteurizer should be followed immediately by hot water. It is well to have the follow-up continuous, being careful of course not to can any diluted juice.

The premises as well as the factory proper should be kept free from crushed or decayed fruit. This debris should be burned or carted away from the factory site.

All metallic surfaces coming in contact with juice should be of resistant metal, such as stainless steel (18–8), monel metal, or block tin. Copper and iron are not satisfactory. All surfaces should be scrupulously cleaned after use.

HANDLING OF FRUIT

If grove-run fruit is used, it must be thoroughly washed (fig. 2) to remove soot, dirt, insects, and other foreign matter which would contaminate the juice during extraction. The fruit is conveyed to large soaking tanks containing such detergents as inexpensive soap powder, trisodium phosphate, or sodium bicarbonate, and then carried through a washing machine equipped with scrubbing brushes. Chlorine water has been used in the washing tanks to reduce spoilage organisms, with considerable success. From the washing machine, the fruit is passed through sprays of clean water, and then into a drying apparatus, where blasts of warm air are blown over it to evaporate adhering water.

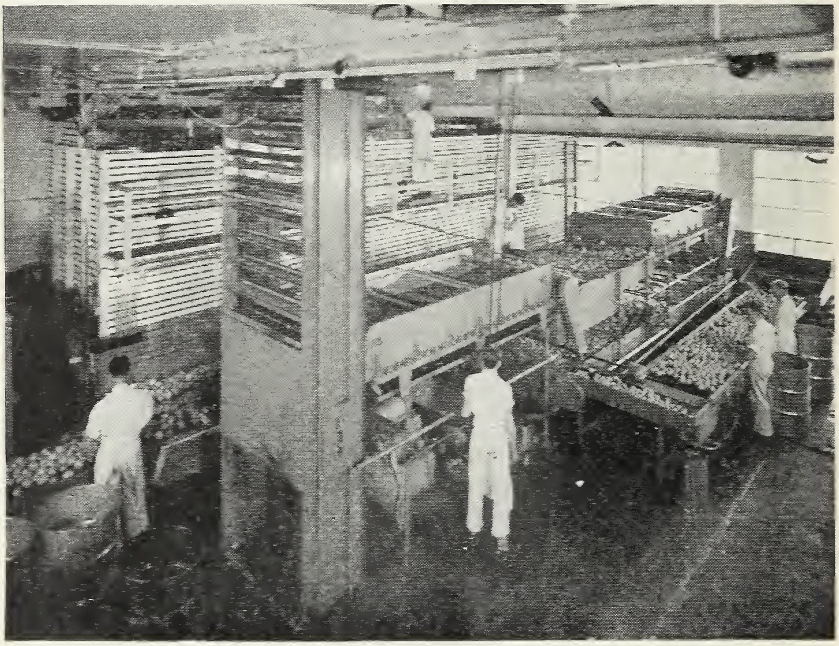

FIGURE 2.—Washing and sorting fruit in an orange concentration plant.

If fruit is obtained from the packing house where it has already been washed, no further treatment may be necessary before extracting the juice, although the careful manager will hesitate to take chances.

EXTRACTING THE JUICE

The washed fruit is unloaded on a conveyor which carries it to the cutters. In hand operations it is easy to cut the fruit at right angles to the longitudinal axis. It is more difficult to do this by machine, owing to the lack of uniformity of the fruit. It is somewhat troublesome to ream fruit that is cut longitudinally, but the yield of juice is the same either way (*32*).

The juice is reamed by pressing the halves over revolving, ribbed cones (fig. 3). These should be properly shaped and should not revolve too rapidly, for there is danger of tearing the fruit, beating in excessive amounts of air, and incorporating undesirable constituents from the rag and peel (*14*).

Formerly reaming was usually done by hand, but now there are several types of mechanical reamers in use. For the most part, these have been devised for use in plants where they are operated, but some are rented to other manufacturers on a royalty basis. By hand one man can ream 18 to 35 gallons of grapefruit juice or 10 to 15 gallons of orange juice an hour.

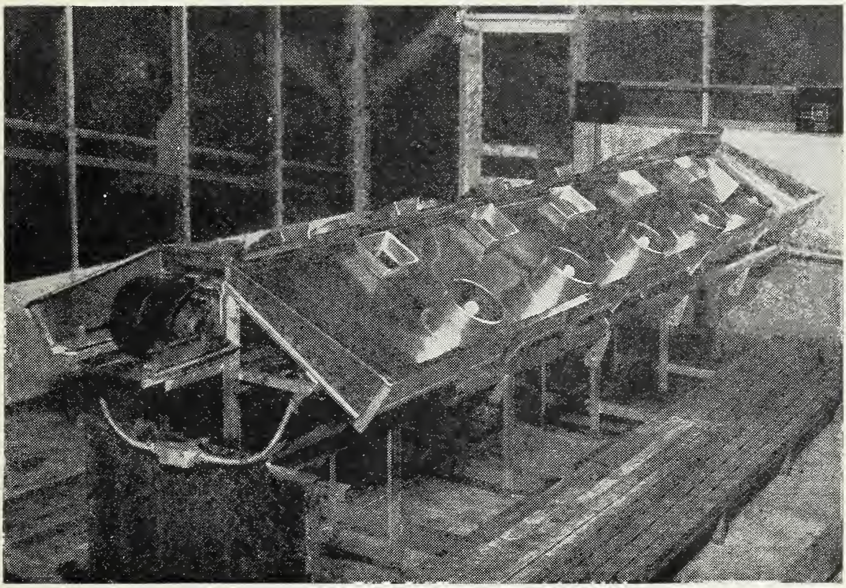

Figure 3.—A reaming table for grapefruit.

Pressing either the whole or the halved fruit in such a way as to incorporate oil from the peel with the extracted juice is undesirable, as this often results in off-flavor in the final product.

Peeling the fruit and then crushing it has been tried, but this method was found not generally feasible. One such peeling device, however, is in commercial operation.

SCREENING THE JUICE

After extraction, excess pulp and seeds are removed from the juice by allowing it to flow through a series of screens of successively finer mesh. The first screen may be 18-mesh and the others as fine as 60-mesh. The screens may be stationary and arranged like shelves in a box, the top screen being the coarsest; but this is not an ideal method because the screens frequently clog and require considerable handling and attention. Vibrating screens overcome this difficulty to some extent. Cylindrical screens, with the intake slightly higher than the outlet and revolving at about 60 revolutions per minute, are also used. These permit continuous discharge of pulp and seeds.

After screening, the juice may be passed through a centrifuge to throw out heavier particles or through a homogenizer to distribute the particles and retard separation. Juice treated by such methods makes a better appearing product and is especially desirable for goods packed in glass.

YIELD OF JUICE

Naturally the yield of juice varies with the condition, variety, and maturity of the fruit, as well as with the locality in which it is grown. Eighty-five gallons to the ton is a good average for oranges, with yields somewhat higher for grapefruit and lower for lemons.

ADJUSTING THE JUICE

After screening, the juice is allowed to flow to a mixing tank. It is sometimes desirable to add sugar to orange or grapefruit juice, especially when the fruit is lacking in character. The addition of sugar to orange juice helps to mask the off-flavor that develops after long periods of storage. It is advisable to add sufficient sugar to grapefruit to increase the Brix-acid ratio to 10. Some canners prefer to have a standard soluble-solids content, about 15° Brix for oranges and 13° for grapefruit.

The quantity of sugar to be added will vary according to the maturity of the fruit. In order to obtain uniform sweetness, therefore, it is necessary to determine the apparent solids and possibly the acid in each batch of juice. Table 1 can be used as a guide in determining the amount of sugar to be used.

TABLE 1.—*Approximate quantity of cane or beet sugar to add to 100 gallons of orange or grapefruit juice to raise the Brix hydrometer reading to definite degrees*[1]

Juice (° Brix)	Quantity of sugar required to raise juice to—									
	18°	17°	16°	15°	14°	13°	12°	11°	10°	9°
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
14	44	33	22	12	--------	--------	--------	--------	--------	--------
13	53	42	31	21	11	--------	--------	--------	--------	--------
12	64	53	42	31	21	11	--------	--------	--------	--------
11	75	64	53	42	31	21	11	--------	--------	--------
10	85	74	63	52	41	30	20	10	--------	--------
9	95	83	72	61	50	40	30	19	11	--------
8	104	92	81	70	60	49	38	29	19	9

[1] Unpublished data developed by G. N. Pulley, U. S. Citrus Products Station, Winter Haven, Fla.

DEAERATING THE JUICE

Deterioration of citrus juices is due to chemical changes, which may or may not be brought about by living organisms. Therefore, juice freed of organisms by sterilization is still subject to deterioration through reactions between normal constituents that become intimately mixed as the juice sacs are ruptured in extracting the juice (*50, 84*).

Some of these substances, known as enzymes, can be inactivated by heat, and for that reason it is advisable to heat certain juices to a temperature that will delay or destroy enzyme activity. Oxygen, a constituent of the air, seems to be necessary for some of the deteriorative changes, so that deaeration is recommended for the more delicately flavored juices. Deaerated juices hold their flavor longer than those containing air.

The juice is deaerated by exposing it in thin films to high vacuum, at least 27 inches. The efficiency of the operation depends on the vacuum, the surface exposed, and the rate of flow through the apparatus (*71*). For small-scale operations (16 gallons per hour), the flasks shown in figure 4 are suitable. Commercial deaerators (fig. 5) are operated on the same principle; thin films of liquid are brought under about 27 inches of vacuum in an inclosed space. Baffle plates, disks, and stirring devices are all used. Inert gases, such as nitrogen or carbon dioxide, are sometimes used to flush out the air, and in some cases these gases are used to fill the space over the juice in the cans.

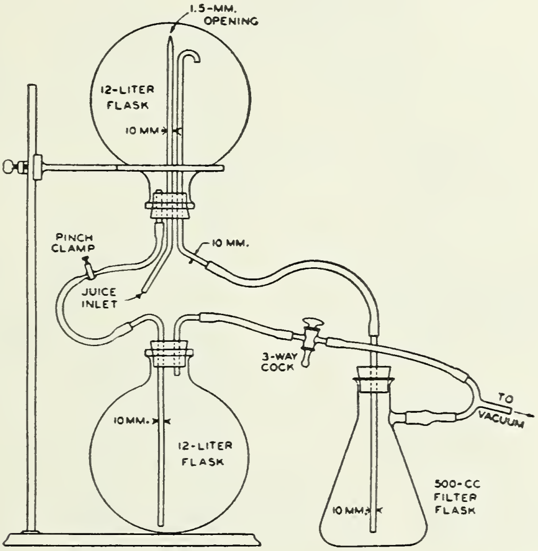

FIGURE 4.—Laboratory apparatus for deaerating juice.

It is of paramount importance to regulate the entire process so that the time elapsing between extracting the juice and sealing it in the container is as short as possible.

The temperature of the juice entering the deaerator should be from 80° to 90° F. for most efficient deaeration.

The deaerator should be placed at least 8 feet above the pump used to circulate the juice through the flash pasteurizer. The pump may be eliminated if it is possible to provide a 34-foot barometric leg to drain the juice from the deaerator.

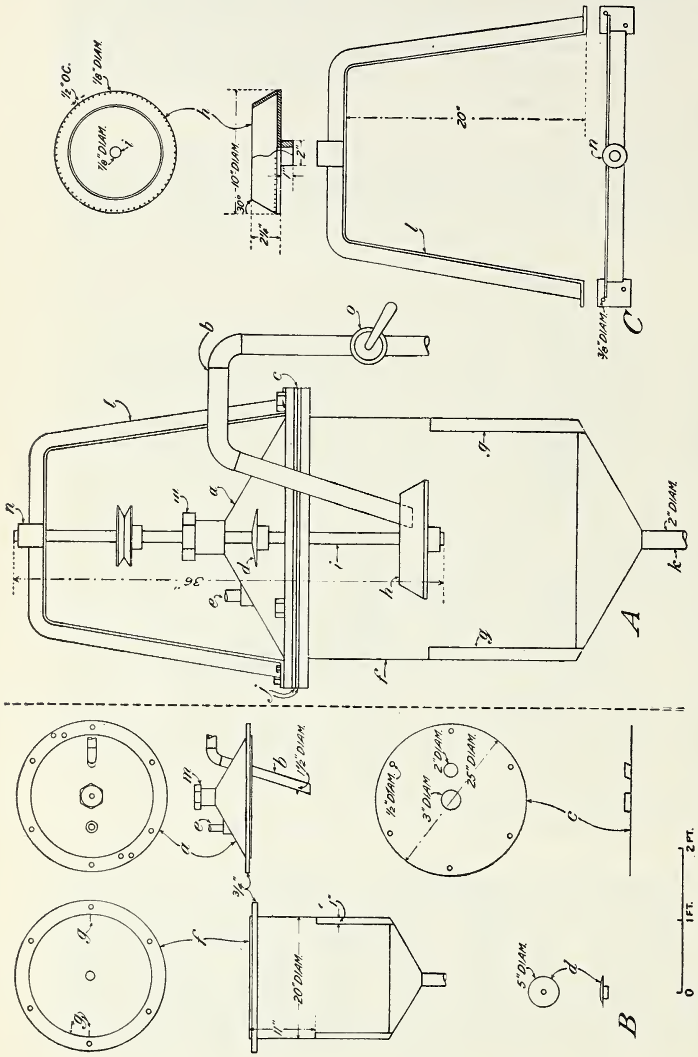

FIGURE 5.—*A*, Apparatus designed by G. N. Pulley for deaerating juice; *a*, Top of deaerator, which is bolted to main body with six ½-inch bolts; *b*, juice inlet; *c*, trip pan; *d*, rotating plate; *e*, vacuum connection; *f*, main body of deaerator (should be at least 21 inches long, with holes in the top flange threaded for ½-inch bolts); *g*, fins to retard whirling of juice (the fins start 11 inches from flange and extend to bottom of tank); *h*, rotating saucer; *i*, drive shaft; *j*, gaskets; *k*, juice outlet; *l*, upper bearing support, which is bolted to flange on top (*a*) with ⅜-inch bolts; *m*, packing gland; *n*, upper bearing; *o*, valve to regulate flow of juice (should be adjusted so that not more than 25 gallons of juice per minute will be delivered to the deaerator). *B* and *C*, Detailed drawings of various parts.

All parts of the apparatus coming in contact with the juice are constructed of 18–8 stainless steel except the rotating saucer, which is constructed of aluminum or aluminum alloy.

PASTEURIZING THE JUICE

The pasteurizer may consist of a flattened tin or stainless-steel tube, exposing the juice in a thin layer. The pasteurizer shown in figure 6 consists of a flattened stainless-steel tube mounted in a 9-inch wrought-iron pipe provided with inlet and outlet for steam and juice. This apparatus has a maximum capacity for heating approximately 500 gallons of juice per hour from 80° to 195° F.

For larger capacities, larger pipe may be used. It should be borne in mind, however, that juice cannot be pumped through the pasteurizer at a greater speed than 200 linear feet per minute without considerable

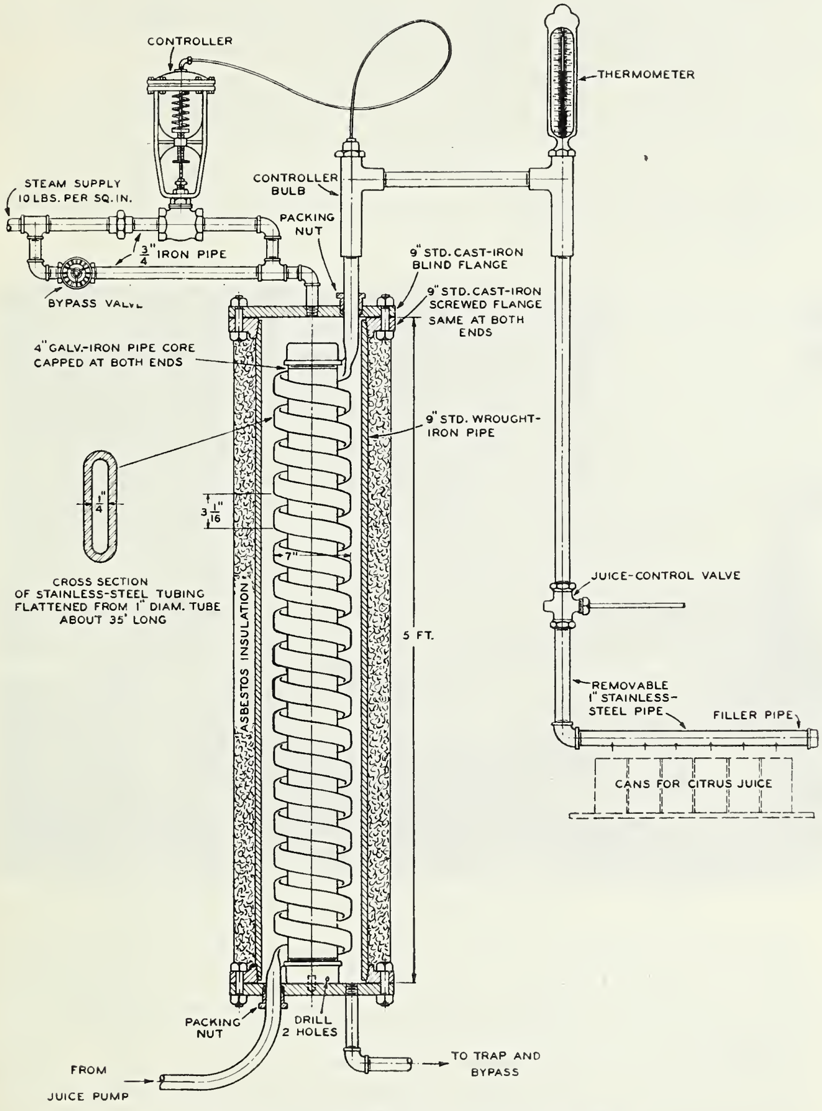
CONTROLLER
THERMOMETER
STEAM SUPPLY 10 LBS. PER SQ. IN.
CONTROLLER BULB
PACKING NUT
$\frac{3}{4}$" IRON PIPE
BYPASS VALVE
9" STD. CAST-IRON BLIND FLANGE
9" STD. CAST-IRON SCREWED FLANGE SAME AT BOTH ENDS
4" GALV.-IRON PIPE CORE CAPPED AT BOTH ENDS
9" STD. WROUGHT-IRON PIPE
$\frac{1}{4}$"
$3\frac{1}{16}$"
7"
CROSS SECTION OF STAINLESS-STEEL TUBING FLATTENED FROM 1" DIAM. TUBE ABOUT 35' LONG
ASBESTOS INSULATION
5 FT.
JUICE-CONTROL VALVE
REMOVABLE 1" STAINLESS-STEEL PIPE
FILLER PIPE
CANS FOR CITRUS JUICE
PACKING NUT
DRILL 2 HOLES
TO TRAP AND BYPASS
FROM JUICE PUMP

Figure 6.—Commercial flash pasteurizer.

loss of pressure by friction. A coil has an advantage over a straight tube as the agitation of the juice is greater and the rate of heat exchange higher.

If tin tubing is used in constructing the pasteurizer, caution should be exercised in flattening the tubing. The tubing should be the heavy-wall type and should be flattened gradually to the desired elliptical cross section. This can be done by removing one of the rolls from a tinsmith's roller and passing the tube back and forth between the adjustable rolls, gradually bringing them closer together until the desired thickness is reached.

Steam supply to the pasteurizer may be controlled by a self-acting diaphragm valve, the thermometer bulb being immersed in the juice leaving the pasteurizer. This temperature should not be higher than 205° nor lower than 199° F. The flow of juice should be so regulated that it is subjected to this temperature for not less than 5 or more than 10 seconds.

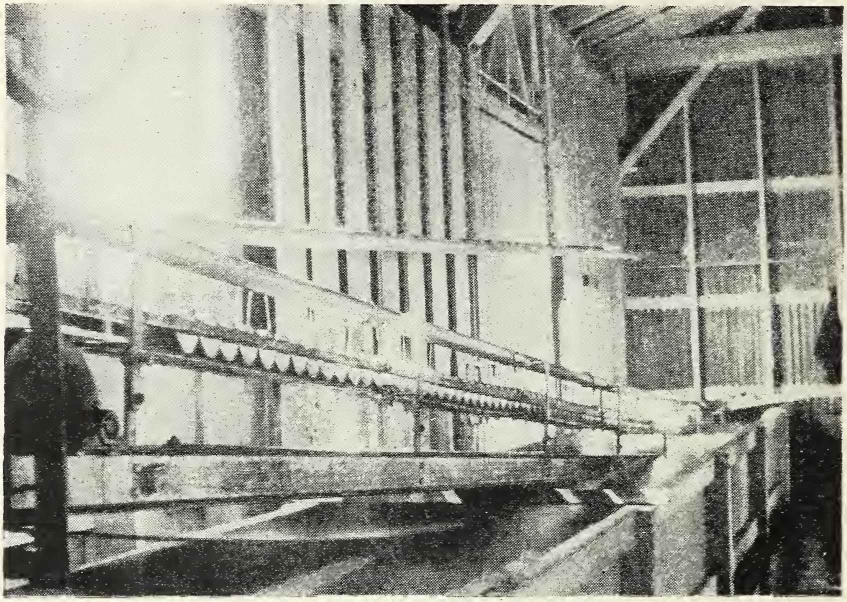

FIGURE 7.—Commercial device for rapid cooling of cans.

The juice is cooled to 170° to 180° F. before it is put into the containers. Vacuum sealing is preferable, and can be completed at between 12 and 15 inches of vacuum, if the juice has been properly deaerated and the temperature is not higher than 176°. Under these conditions, there is no danger of boiling and loss of juice. When cool, the containers will have a vacuum of about 20 inches. Large containers (No. 5 and No. 10 cans) are closed at atmospheric pressure, as closing under vacuum would cause "paneling" or flattening of the sides of the can. After the containers are sealed, they are turned over so that the hot juice comes in contact with the lid, then cooled as rapidly as possible, preferably by rotating and spraying with cold water. Figure 7 shows a commercial device for rapid cooling.

CONTAINERS

Orange juice can be packed in enamel cans if the juice has been thoroughly deaerated, or in glass to retain the natural flavor. That packed in plain tin tends to bleach and take on a metallic flavor. It is necessary to use a special citrus enamel, which has been developed by the manufacturers of cans. Some operators fill the head space in their cans with nitrogen.

Grapefruit juice is packed in plain tin cans, enamel cans not being considered necessary (*79*).

Glass containers are also used. Unfortunately citrus juices turn dark after 8 or 10 months' storage (*40*). The higher the temperature of storage, the more rapid the darkening. However, since darkening is due primarily to oxidation and not to light, the less air the juice contains, the less the danger of darkening. Deterioration of these juices is retarded by storage at low temperatures. If feasible, they should be stored at between 50° and 60° F. (*13*, *43*).

The closures of glass containers are usually of tin, not lacquered on the inside. The containers are stored upside down so that the juice is in contact with the metal. If packed in bottles, the crowns are provided with tin or aluminum spots. Such crowns are more easily sterilized, and there is no danger of cork disintegrating and contaminating the juice. The amount of metal present is probably too small to have any influence on the speed of darkening.

It has already been pointed out that the pulp of citrus juices separates on standing and that centrifuging or homogenizing the juice prevents this separation to some extent. However, if juice is packed in glass, the separation may be apparent to the consumer. To mask this separation, it is customary to use containers of stippled or deeply colored glass or to cover as much of the surface as possible with the label.

Lemon and Lime Juices

If the fruit is large, as is the case with lemons and Tahiti limes, the juice may be extracted by reaming in the same manner that orange and grapefruit juices are extracted. When too small to ream, the whole fruit is crushed and screened, and the juice is then passed through a supercentrifuge to remove excess oil.

The juice is deaerated and flash pasteurized according to the method described under orange and grapefruit juices. It is not advisable to add sugar.

Glass containers seem to be favored by packers of lime juice. The juice darkens in glass, however, the same as orange or grapefruit juice.

Lemon and lime juices also undergo changes in flavor during storage; therefore storage conditions should be similar to those described under orange and grapefruit juices.

Blends

A phase of the fruit-juice industry much neglected in this country is that of blending. Many juices not entirely satisfactory in flavor or too expensive when packed alone can be blended with milder or cheaper juices with very satisfactory results.

Tangerine juice blends well with orange juice, some of the berry juices make fine blends with grapefruit juice, and mild-flavored grapefruit juice blends well with orange juice. Lemon and lime juices can be used to increase the acidity of mild products. The juice of the hybrid tangelos makes good blending material; a few contain juice that is pleasing when put up alone.

FROZEN JUICE

It is possible to preserve citrus juices by freezing in either glass or tin containers (*17, 37, 82*). It has been satisfactorily frozen in 4- and 8-ounce bottles and in cans of all sizes up to 5 gallons. As there seems to be no advantage in freezing in glass, nearly all the commercial juice is frozen in tins. Although frozen juice deteriorates much less rapidly than the pasteurized product, the same care in deaerating and rapid handling should be used as in putting up pasteurized juice (*17*). Inasmuch as the product is to be defrosted before using, there is not the necessity for the instantaneous or very rapid freezing that there is where smooth texture is desirable. On the other hand, as long as the juice remains in the liquid state, certain chemical reactions take place, and the juice deteriorates to that extent (*77*).

The most efficient type of cooler is one in which the receptacle comes in direct contact with the refrigerant while both are in motion. The motion of the juice container should be such as to stir the contents, thus constantly presenting fresh liquid to the cold sides. When the sealed containers are frozen by contact with cold air, the air should be circulated. With small containers, a vacuum seal may be used to advantage; with gallon or larger cans, high vacuum is not possible. They should be filled as full as can be done without causing them to bulge on freezing. There are devices on the market that slush freeze orange juice, delivering it in a continuous flow. The containers are sealed and stored in cold rooms to finish the freezing. Freezers of the types that incorporate air in the juice should not be used. Figure 8 shows a freezer of the vertical type.

After freezing, orange juice should be shipped and stored at 0° F. It will retain its flavor for 2 years or more when properly prepared and handled. Storage and shipping temperatures should be as uniform as possible, if maximum quality is desired.

Freezing is without doubt the best way of retaining the original composition and flavor (*20*). At present there are obstacles in the transportation and final distribution of frozen juices, but with the development of this form of preserving food, they will be overcome. There is some demand for frozen lemon juice for bar trade. The same method of preparation can be used.

BEVERAGE BASES

SIRUPS

For a number of years, it has been customary to concentrate citrus juices for use in the preparation of bottled beverages (*5, 70*). Later another commodity made its appearance. This was juice to which sugar or sirup had been added together with fruit acid, flavor, and color. The acidity was usually obtained with citric or tartaric acid, the flavor with citrus oils, and the color with a dye permitted for use in foods. This product was often called a beverage concentrate, which was misleading, as the product was not concentrated but was a mixture of natural juice with sugar sirup, artificially acidified, flavored, and colored. Some of the better grades were acidified with lemon juice. The same type of product is now being marketed for the preparation of orangeade, and has a very large distribution in some parts of the country. The Food and Drug Administration should be consulted regarding the labeling of artificially colored beverages.

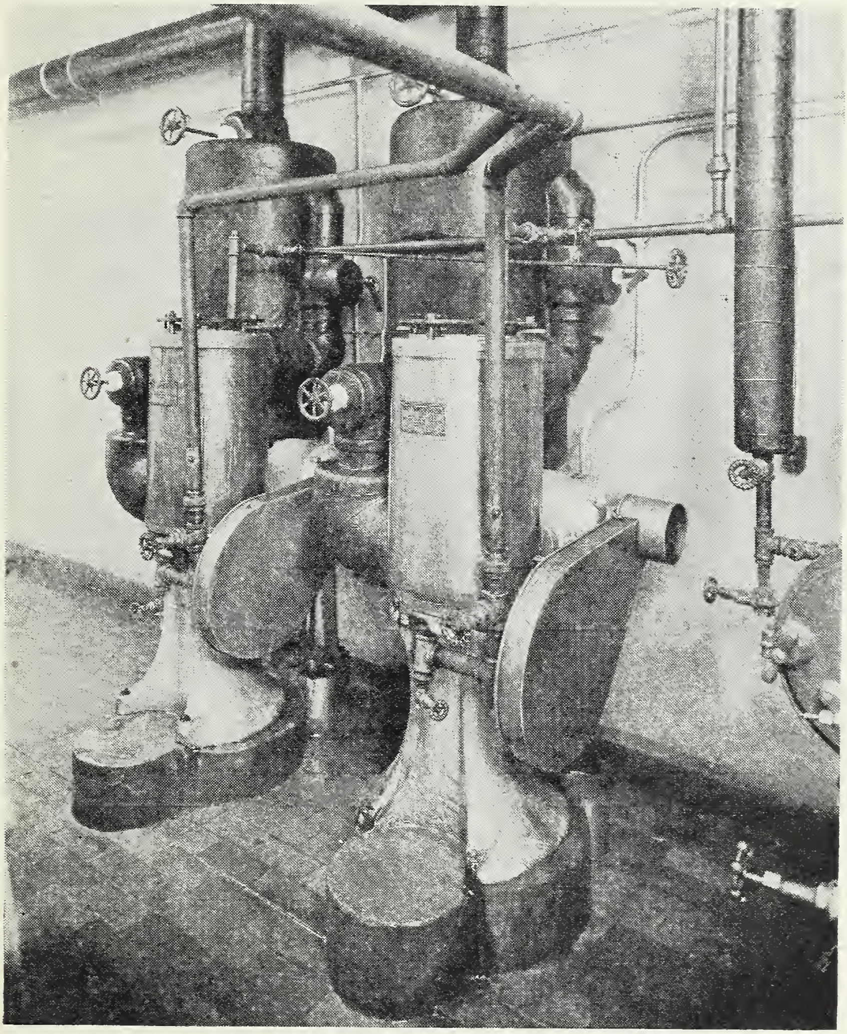

FIGURE 8.—Vertical-type freezer for citrus juices.

When properly used, these beverage bases have a legitimate place in the beverage industry. Too often, however, the distributor in making up the beverage for consumption reduces the amount of juice in the finished product to such an extent that its nutritive value becomes infinitesimal. After the product leaves the hands of the manufacturer, he loses control of it, and often the distributor leads the consumer to believe that it is pure juice or that it contains a much larger proportion of juice than it does. If made up according to directions, most of the high-grade products will carry from 15 to 20 percent of juice to the consumer.

Either hand-reamed or machine-pressed juices may be used in the preparation of a beverage base. Machine pressing may extract too much oil from the peel. Hand reaming extracts little or no oil, so that a combination of the two methods of extraction can be used to give the desired proportion. The oil content may also be built up by the addition of an emulsion of cold-pressed orange oil or of terpeneless orange oil. Juice prepared by grinding and pressing the whole fruit contains too much oil and has poor flavor and keeping qualities because of other substances extracted from the peel.

After extraction, the juice is run through a 20- to 24-mesh screen to remove seeds and coarse pulp. Sugar, color, and citric acid or lemon juice are added, and the mixture is thoroughly mixed with a mechanical stirrer. The base is deaerated, flash pasteurized, and cooled before it is put into the containers. From the pasteurizer, the product flows through a cooling coil that lowers the temperature from 200° to 170° F. At this temperature, the base is filled into the containers. Gallon size (No. 12) citrus enamel cans are commonly used. The cans are immediately cooled, with agitation, under a shower of cold water. The cooled cans are dried and, if they are to be stored, may be wiped with a cloth soaked in mineral oil to prevent rusting. The best method for preservation of flavor is storage under refrigeration at 55° to 60°. However, the product has fair keeping qualities if given preferred storage in a cool place.

BEVERAGE BASES PRESERVED WITH SULFUR DIOXIDE

There has been an export market for a limited amount of bases for use in the preparation of beverages such as orangeade, lemonade, and limeade, squashes, and variously flavored barley waters. The beverage base is diluted with water, sweetened, acidified, and flavored to suit the trade to which the bottler is catering. The trade calls for three types of products—"clear juice," "green juice," and "whole fruit with top oil." Clear juice is made by pressing the cleaned fruit through a screw press, screening, and separating the undissolved oil. The resulting liquid is treated with 1,200 parts per million of sulfur dioxide and allowed to stand until the clear juice can be siphoned or decanted off. On analysis, the product will show about 800 to 900 parts per million of sulfur dioxide, but the amount will be greatly reduced by the time it reaches the bottler.

"Pulp juice" or "green juice" usually consists of the material obtained by passing peeled fruit through a screw press and then through a screen with 1/8-inch holes. It is a turbid product and may be put up with added juice sacs if these are desired.

The whole fruit with top oil is similar to the green juice except that the fruit is not peeled, or only partly peeled, before passing through the screw press. It contains the full amount of juice sacs and some peel and oil.

These bases are usually packed in paraffined white oak barrels, and preserved with approximately 1,200 parts per million of sulfur dioxide. The preservative is commonly added as bisulfites or metabisulfites of soda or potash. The bisulfites contain from 50 to 60 percent of sulfur dioxide, and the metabisulfites somewhat more than 60 percent. As the demand for this type of product varies considerably, it is always best to have an understanding with the buyer as to the character of the material desired. Orange, grapefruit, lemon, and lime bases are all in demand and are quoted in the trade.

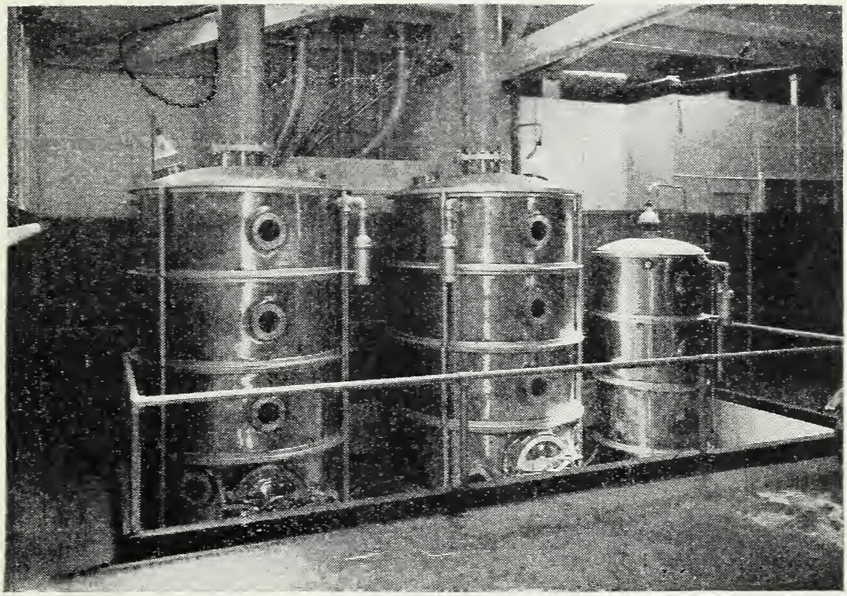

Figure 9.—Apparatus for concentrating juice under vacuum.

Concentrated Juice

The preliminary steps in obtaining juice for concentration are the same as for canning or freezing, except for the deaeration, which takes place as soon as the liquid begins evaporating in the vacuum pan. It is common practice to add a small amount of sugar (5 percent) to the juice before beginning the concentration. The well-screened juice is drawn into the vacuum pan, which is usually the glass-lined (enameled) type. It is placed under high vacuum until foaming ceases, after which heat is applied and the liquid is concentrated as rapidly as the low temperature and high vacuum used will permit. Figure 9 shows the apparatus used.

Returning the volatile compounds that come over at the beginning of the evaporation does not seem to improve the flavor of the concentrate. The largest manufacturers of concentrated citrus juices do not use this method, although its use seems advantageous with some other fruit juices.

When the required density has been obtained, the concentrate is run into the containers, which are then closed and stored at reduced temperatures. Concentrates are most often used in the preparation of the so-called soft drinks. Owing to the high content of vitamins (*30*) and alkaline salts, there is considerable demand for fruit-juice concentrates by pharmaceutical houses. Flavoring matter and color are sometimes packed separately and added to the finished beverage by the bottler.

Powdered Juice

Attempts have been made to place powdered citrus juices on the market. The chief obstacle seems to be the property of the powdered product to absorb water rapidly and become pasty. In order to remedy this difficulty, the juice is mixed with a spreader, usually glucose, corn sugar containing 70 percent of dextrin, or other material that does not take up water rapidly. Frequently the amount used (40 to 70 percent) is out of proportion to the juice, but is necessary in order to obtain a product that will keep without caking. Pectin and pectate products have recently been introduced for this purpose and are said to permit a higher concentration of juice solids in the final product.

Two types of apparatus are used: A nozzle delivering a spray under high pressure into a current of warm air, or a rapidly revolving disk upon which the liquid is dropped and delivered at the periphery as a fine mist which falls through warm air.

VINEGAR

Excellent vinegar can be produced from orange juice. On a large scale, it probably could not compete with the established apple vinegars, but when properly handled and sold as a specialty, it is possible to sell considerable quantities. Before manufacturing vinegar from citrus juices, the regulations of the Federal Alcohol Tax Unit covering the subject should be consulted.

The temperatures in most of the citrus-growing regions are too high in summer to permit satisfactory use of the usual farm method of barrel storage in making vinegar. The following rapid-roller process will produce a finished product in from 60 to 90 days. A rapid generator producing from 30 to 50 gallons a day can be used for commercial production (*68*). Vinegar can be made from both orange and grapefruit juices by this process. The product made from grapefruit juice, however, does not have the amount of acetic acid required by the Federal standards for vinegar, and its sale under Federal or State food and drug laws might be prohibited, unless it is properly labeled.

Apparatus

The generator may be made from an ordinary vinegar or whiskey barrel (fig. 10). The hoops are so loosened that one head can be removed from the barrel, after which a small rack is fitted in to form a compartment throughout the entire length of the barrel, about 5 inches below the bung, to be filled later with beechwood shavings or corncobs. To build this rack quickly, set slats, 3 inches wide and half an inch thick, half an inch apart in grooved endpieces. Support the rack at each end by a 2- by 4-inch piece cut in lengths to make the rack fit in at least 5 inches below the bung. The 2 by 4's usually are joined by a 1- by 2-inch crosspiece. Set the rack in place, fill the compartment with cobs or shavings, rehead the barrel, and bore in each end three 1-inch holes, slanting downward and opening just beneath the bottom of the rack that holds the shavings or cobs. Use grooves or dowels, or if more convenient, hardwood pegs to fasten the rack to the 2 by 4's to hold it together. Nails made from iron or any other metal should not be used. The capacity of such a generator is from 30 to 40 gallons.

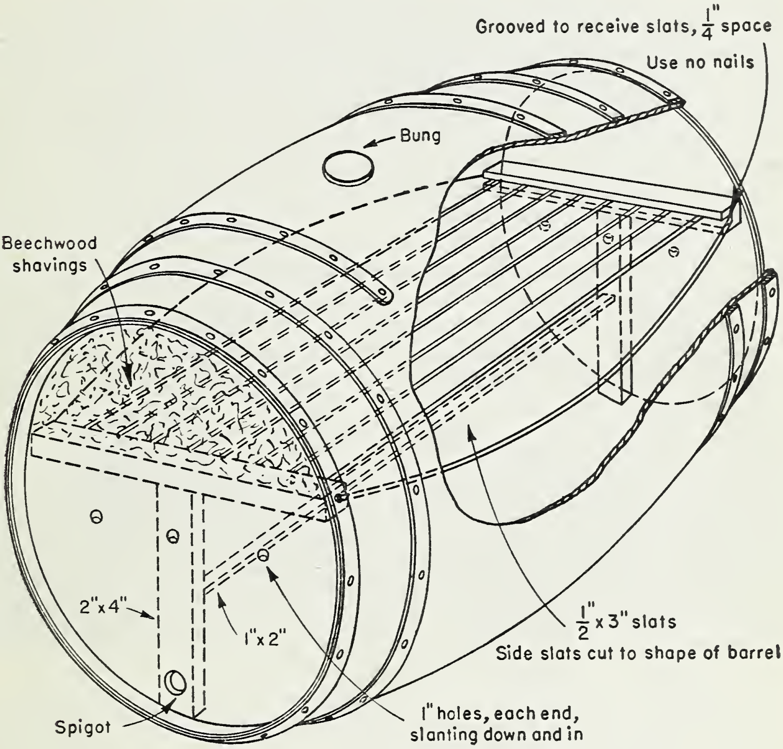
Grooved to receive slats, 1/4" space
Use no nails
Bung
Beechwood shavings
2"x4"
1"x2"
Spigot
1/2"x3" slats
Side slats cut to shape of barrel
1" holes, each end, slanting down and in

Figure 10.—Small vinegar generator.

Procedure

Press the juice from the oranges and strain out all large particles of fiber or peel. Add 1 pint of brewer's yeast to 40 gallons of juice, or use six cakes of compressed yeast that have been softened in orange juice. Set the juice aside in a barrel, keg, or tub for several days, keeping it loosely covered with a cloth as a protection against flies. It is best to keep it at a temperature of 85° F. As soon as fermentation ceases, usually from 3 to 5 days later, according to the temperature, strain the juice again.

If the generator has not been used before or if it has been standing idle for some time, scald it thoroughly before using. This can be done by blowing steam into the bung, or by giving it a thorough washing with hot water. After the water has been completely drained out, add about a quart of good vinegar (cider, malt, or orange) that has not been pasteurized. Allow the vinegar to flow over the shavings and cobs and the inside of the barrel. Now add the fermented orange juice through the bung, close the bung tightly with its wooden stopper, and plug the holes in the ends of the barrel with ordinary raw cotton. Several times, if possible, but at least once each day, replace the cotton plugs with wooden pegs, turn the barrel over so that the bung is at the bottom, and shake three or four times to bring the juice in the barrel in contact with the shavings or cobs. After rolling the barrel back into its original position, remove the wooden pegs and reinsert the cotton plugs. An excellent vinegar is produced by repeating this treatment daily for 60 to 90 days, if the temperature is above 80° F.

When the material is sufficiently acid, remove it from the barrel, place it in clean, hot, glass bottles, and cork tightly.

The vinegar may be sterilized readily by heating the filled but uncorked bottles in boiling water for 15 to 20 minutes or by passing it through a flash pasteurizer. This treatment prevents any deterioration in quality and appearance that might otherwise occur during storage.

CITRIC ACID

Citric acid is the predominant acid of citrus fruits, but it is also widely distributed among other fruits. Until recent years, lemons, limes, and bergamots were the sole sources of the commercial supply (*15*). Recently large quantities of this acid have been made by growing certain species of mold on sugar solutions, and smaller quantities have been recovered from pineapple waste. Oranges, grapefruit, and other mildly acid citrus fruits do not contain sufficient citric acid to make its economical recovery possible.

Attempts to crystallize the acid directly from the juice on a commercial scale have so far been unsuccessful (*64*). The manufacture of citric acid is a complicated process, not adapted to small-scale operations (*87*). Factories should be of sufficient size to afford chemical control. The apparatus throughout should be constructed of acid-resistant materials.

As fruit passes into the plant (fig. 11), it should be washed and sorted if oil or other special products are to be made. It is then crushed and passed into a continuous screw press or other pressing device. If the residues from the presses can be economically washed and re-pressed, this is usually done. The juice and washings are screened to remove the coarser suspended matter, the screenings being returned to the press.

In large-scale operations, it pays to ferment the juice at this point. Complete fermentation, however, is not necessary, the operation being carried out until the juice will filter readily with a minimum application of filter aid. Diatomaceous earth (kieselguhr) can be used with the fresh juice, and if enough is used the filtration will be satisfactory. Treatment is carried on at boiling temperature.

The juice is usually filtered in a plate-and-frame press, and the press cake is washed and discarded. If available, a continuous press can be used for this operation. The clarified liquid is precipitated with either chalk (calcium carbonate) or powdered lime. These reagents must be pure; both magnesium and iron should be absent or should be present in traces only. The acidity of the juice may be determined, and almost all the acid neutralized with the lime. Enough chalk to complete the reaction is then added. These operations should be carried out with constant stirring and at approximately boiling temperature. The precipitated citrate is allowed to settle and is washed by decantation with boiling water. If a filter press is available, the citrate can be filtered in this way and washed with boiling water. It is finally transferred to the decomposition vat, where it is suspended in water or in the acid washings from a previous batch of calcium sulfate (gypsum), and enough sulfuric acid (65° Baumé) to decompose it is added. The quantity of sulfuric acid necessary for this purpose must be determined by analysis of the citrate. After thorough stirring for about one-half hour, without heating, a small sample is drawn off and tested with calcium chloride for an excess of sulfuric acid.[4] Excess of sulfuric acid must be

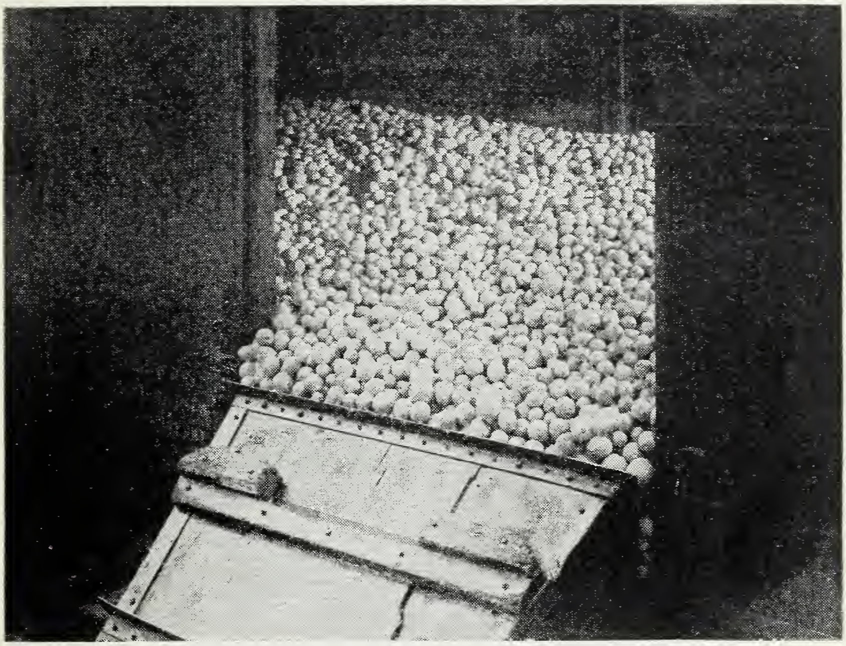

FIGURE 11.—Unloading lemons at a large-scale lemon-products plant.

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[4] Wilson (*87, pp. 555–556*) gives the following test: "* * * add about 5 cc. of 45 per cent $CaCl_2$ solution to an equal volume of the filtered liquor. A faint precipitate of calcium sulfate should be noticeable after holding in the steam bath 5 min., indicating an excess of not more than 0.2 per cent sulfuric acid."

avoided; any occurring should be neutralized by the addition of more citrate.

Usually about 3 hours are allowed for the decomposition. The calcium sulfate is allowed to settle, and the supernatant acid liquor is drawn off. The precipitate is washed until free of acid, the washings being used in preparing the next batch of citrate for decomposition. If the technique of the operation up to this point has been carefully followed, the acid liquor should contain between 10 and 15 percent of citric acid and should be light amber in color.

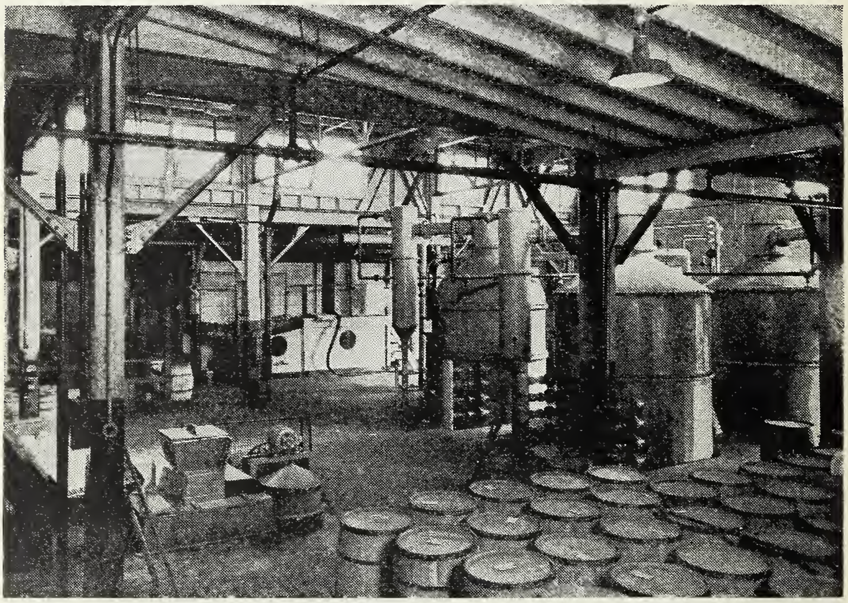

FIGURE 12.—Vacuum pans for citric acid production.

When waste steam is available, this liquor can be evaporated to 20° to 25° Baumé in open lead-lined evaporators, heat being supplied by means of lead steam coils. The liquor should be agitated by compressed air or by other means, and should not be allowed to boil briskly. Final evaporation should be made at low temperature under vacuum (fig. 12), to a concentration of 37°. In the past most of the vacuum evaporators have been lead-lined, necessitating the removal of the lead by soluble sulfides before the final recrystallization. In new installations, lead-free noncorrosive alloys are being used.

The concentrated liquor is filtered to free it of suspended calcium sulfate and run into shallow crystallizers, where the first crop of crystals will appear in about 3 days. Gentle agitation will produce a granular deposit if this is desired. The mother liquor is drained off and reboiled for further deposits of crystals. When no longer advantageous to do this, it is reprecipitated with lime and again decomposed.

The first crop of crystals is dissolved in warm water, and the lead impurities are removed by treatment with soluble sulfides. Iron and nickel are removed by treatment with a ferrocyanide. The organic coloring matter in the liquor must be removed by decolorizing agents, and these must be carefully selected to avoid soluble mineral impurities that will raise the ash content of the final crystals. Under the United States Pharmacopoeia standard, ash must not exceed 0.05 percent.

The final crystallization must take place in vessels where no metallic or other contamination is possible. In this country, monel or other resistant metal is used. Porcelain is used in Germany, and Italian works refer to the use of wood polished with plumbago. Plain wood chips off, leaving splinters in the crystals; porcelain is too expensive in this country; and stone and enamelware chip when force is used to remove tightly adhering crystals.

CITRATE OF LIME

When citrate of lime is to be prepared for sale, the above process can be carried out through the filtration of the citrate (p. 21). Figure 13 shows the filter presses used for citrate of lime. Instead of going to the decomposition tank, the product is dried at below 220° F.

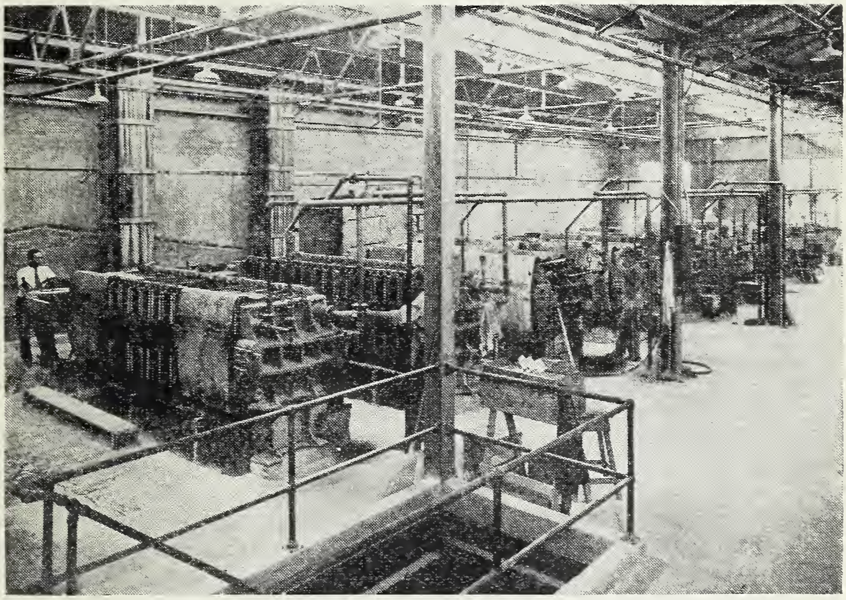

FIGURE 13.—Filter presses for citrate of lime.

Often both the fermentation of the juice and the pretreatment with kieselguhr are omitted. The juice is screened and neutralized, and the precipitated citrate is filtered, washed, and dried. Products thus made, however, are usually impure.

CANNING SEGMENTS

Grapefruit

In canning grapefruit segments, the fruit is washed as described under Preserving Citrus Juices (p. 6).

The fruit is either hand-peeled or lye-peeled. In the former case, the peel is removed with a stainless-steel cobbler's knife, the outer membrane of the segments being removed with the peel. If the fruit is to be lye-peeled, it is first passed through a bath of hot water, 196° to 200° F., for about 5 minutes. This plumps the peel so that it may be readily stripped off by hand. The outer membrane of the segments is disintegrated by passing the fruit through a hot lye bath (containing 1 to 3 percent of sodium hydroxide) for approximately 12 seconds. It is then passed beneath sprays of water to remove the lye and detach the disintegrated membrane.

Some canners claim a high-quality pack can be obtained only by hand peeling. This is open to some dispute, but it is certain that lye peeling cannot be used with tender or overripe fruit. The yield per field box is greater for lye-peeled than for hand-peeled fruit. The former averages 33 No. 2 cans per field box (100 pounds), whereas the latter method gives from 24 to 27 cans per field box.

The fruit, whether hand- or lye-peeled, now goes to the sectionizing tables. Here the sections (hearts) are removed from the membranes by hand labor, using stainless-steel or aluminum knives. The exact operation is almost impossible to describe. The fruit is either put on a spindle or is held in the operator's hands. A knife somewhat like a letter opener but with a broader base is deftly inserted between the membrane wall and the section, and a slight inclination of the knife separates the whole section from its membranous covering. The work is done by girls who have acquired a high degree of skill and can usually section a fruit in about 15 to 20 seconds. The seeds are removed by tapping the sections against each other.

The sections are placed on stainless-steel or aluminum trays and conveyed to the packers. They are put into the cans by hand, usually arranged around the circumference so that a hole is left in the center of the pack. This is popularly known as the pineapple pack because the sections are so arranged that they somewhat resemble canned sliced pineapple. From 16 to 18 ounces of fruit are put into each No. 2 can, and sugar sirup or granulated sugar is added. Usually 45° to 47° Brix sirup is used at the rate of 3½ to 4 ounces for each No. 2 can. Unlacquered cans are used, and a ⅜-inch head space is allowed.

The filled cans are either vacuum-closed and processed or exhausted in hot water. If vacuum-sealed, they are heated at about 185° F. for 35 minutes, and then passed through a cooling tank. If not vacuum-sealed, they are passed through an exhaust box for 30 to 35 minutes at 180°, sealed while still hot (a No. 2 can will have a temperature of about 146° when it leaves the exhaust box), and then heated for 16 to 30 minutes at 176° to 185°.[5] The cans are then cooled by passing beneath sprays of water and into a cooling tank. When leaving the cooling tank, they should have a temperature less than 100° to prevent

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[5] Times and temperatures are for No. 2 cans.

"stack burn" or softening. A fan may be used to facilitate drying the outside of the cans, and this also aids in preventing rusting. The cans are stored on their sides for about 10 days to detect leaks and to allow the sections to harden.

Mature fruit should be used for canning segments. If immature fruit is used, the product may be excessively bitter, owing to the presence of naringin, and the naringin may crystallize and produce clouding in the juice (*28*, *29*).

Broken segments are packed and sold as "broken sections," or they are further broken down, preserved with sulfur dioxide, and packed in paraffined oak barrels.

The tenderness of some types of grapefruit makes special precautions necessary in segment canning. The segments can be successfully canned, however, if fruit of suitable size and of sufficiently regular segments is selected. Knife peeling is preferred to lye peeling.

The segments are graded according to size and quality, and placed, by hand, in No. 2 cans with 40° Brix sugar sirup. Heavier sirup tends to give an insipidly sweet product with the mild types of grapefruit, but is satisfactory for the more acid types. When the water available for preparing sirups contains the equivalent of 300 parts per million of calcium salts, it has an appreciable effect in toughening the canned segments.

The filled cans are exhausted at 180° F. for 15 minutes, and then processed at 180° for 15 minutes. Cans are then cooled without agitating and stored for 10 days before they are labeled (*6*, *12*, *48*).

ORANGE

Canning orange segments alone has not been altogether successful commercially (*3*). The sections bleach to a certain extent, and become tough, leathery, and tasteless. Orange hybrids, however, are combined with grapefruit segments in a "citrus salad" pack. When packed in this manner, the product is satisfactory. Oranges should not be lye-peeled, as the heat damages the flavor. Processing is carried out in the same manner as for grapefruit segments.

Several canned citrus fruits have made their appearance on the market from time to time. Canned Japanese mandarin oranges are regularly sold in this country (*3*), but so far, no extensive demand has developed.

FROZEN CITRUS FRUITS

Orange slices and grapefruit hearts have been frozen in both glass and cans (*17*). Only fair success was obtained with friction-top cans, but vacuum-sealed cans and glass jars gave very satisfactory results. The packages were evacuated and capped before freezing. Orange slices were packed in 20-percent sirup; grapefruit hearts in 50-percent. Eight-, ten-, and twelve-ounce packages, closed under 27 inches of vacuum, were used. Freezing in brine at −30° F. took place in 30 minutes. After storage at 7° for 250 days, the containers retained 22 inches of vacuum. Flavor was somewhat better when carbon dioxide was used to fill in the head space. Fruit covered with sirup kept its flavor better than that packed dry.

ALCOHOLIC BEVERAGES

CITRUS WINES

Before attempting to manufacture alcoholic beverages, the Federal Alcohol Administration of the United States Treasury Department should be consulted regarding regulations covering production, storage, and sale. The addition of sugar and water to the juice before fermentation, and of sugar and alcohol after fermentation, are covered by regulations. The regulations in force at the time of writing are referred to in this circular, but manufacturers are strongly advised to consult with the revenue authorities before venturing into the manufacture of alcoholic beverages, as changes in the regulations may have been made.

PREPARATION OF MUST

The juice is extracted by cutting the washed fruit in half and reaming, as described in the preparation of citrus juices. Crushing or grinding the fruit is not satisfactory, as such methods incorporate too much oil, which not only retards fermentation but also imparts a bitter taste. The reamed juice is screened by means of a 20-mesh screen constructed of stainless steel or other corrosion-resistant material.

Neither orange nor grapefruit juice contains sugar enough to produce a wine with a satisfactory alcoholic content. It is therefore advisable to add sugar.[6] Either cane, corn, or beet sugar may be used, but brown sugar is not recommended as it imparts a molasses-like flavor and aroma to the product (*31*, *39*).

The Internal Revenue regulations permit the addition of such an amount of sugar and water solution as will not increase the volume of the resulting product more than 35 percent. Either cane, beet, or dextrose sugars of 95 percent purity may be used, but the original juice must contain not less than 0.5 percent of acid and the finished product not more than 13 percent of alcohol.

Usually the amount of sugar to be added ranges from 1 to 1¾ pounds per gallon. If corn sugar is used, approximately 10 percent more (1¼ to 2 pounds) should be added to compensate for the water in this sugar.

PREPARATION OF YEAST STARTER

To obtain uniform results, pure cultures of wine yeast should be used. Such cultures may be obtained from commercial concerns, whose addresses will be supplied by the Agricultural Chemical Research Division of the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture, Washington, D. C. The cultures, which will be received in a test tube, should be handled as follows:

Scald a clean pint bottle in boiling water for 20 minutes.

Add about 1 tablespoon of sugar (either cane, corn, or beet) to one-half pint of orange juice (grapefruit or tangerine juice may be used).

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[6] See par. 76, regulations No. 7, of the Bureau of Internal Revenue.

Boil the mixture gently for about 15 minutes in a covered aluminum or enamel kettle. While it is still boiling, pour it into the scalded, hot, pint bottle and plug the mouth of the bottle with fresh, clean, sterile absorbent cotton. Set the mixture aside to cool overnight.

As cotton plugs are easily contaminated, it is better to renew them after each operation rather than run the risk of spoiling the culture.

When ready to use, remove the cotton plug from the culture tube and pass the neck of the tube through a gas or alcohol flame a few times. Now heat the neck of the pint bottle containing the orange juice in the same manner as the culture tube was heated, and remove the cotton plug from the mouth.

Fill the culture tube half full with the juice from the bottle.

Stir carefully with a stiff wire that has been heated to redness and allowed to cool. Do not touch the wire with the fingers to see if it has cooled, as this would contaminate it. It will cool in about 20 seconds.

Pour the stirred liquid from the culture tube back into the bottle of orange juice.

Plug the bottle again with a piece of sterile cotton. Set it aside in a warm place, about 70° F. It should be in active fermentation within 48 hours after inoculation.

In the meantime, add about 1 cup of sugar to a gallon of citrus juice and boil gently for 15 minutes in a covered aluminum or enamel kettle.

Sterilize a clean gallon bottle with boiling water, being careful not to break the bottle by too rapid heating.

Pour the hot juice into the hot bottle until it is about one-half to three-fourths full. Then plug with sterile cotton. Allow it to stand until cool. The gallon of juice should not be prepared too far in advance, as it may become contaminated if held longer than 3 days.

Shake the pint bottle of inoculated juice carefully to avoid wetting the cotton plug, flame the neck of the bottle, and remove and discard the plug.

Pour one-half to three-fourths of this juice into the 1-gallon batch and plug with sterile cotton. Shake carefully.

Heat the neck of the pint bottle by passing it through a flame, plug with sterile cotton, and set aside in the ice box. This may be used to inoculate another pint of sterile juice in the same way as the original culture.

The 1-gallon batch is now placed in a warm place. In about 3 days it will be in active fermentation.

Thoroughly clean a 10-gallon container with boiling water. If a barrel is used, this should be steamed or treated with boiling water three times.

Fill the container three-fourths full with juice that has been prepared in a strictly sanitary manner and is free from excessive amounts of peel oil. The juice does not have to be sterile.

Add 10 pounds of sugar. When it has dissolved, add the 1 gallon of actively fermenting juice.

About 10 gallons of actively fermenting juice is sufficient to start 100 gallons of the juice to be fermented; 100 gallons of actively fermenting juice will start 1,000 gallons of juice.

The starters should be prepared in a clean room, as free from drafts as possible.

FERMENTATION

After inoculation with the pure 48-hour starter, fermentation should begin in about 4 hours. The starter should not be more than 48 hours old, otherwise fermentation will be slow in starting. The addition of ammonium carbonate or phosphate induces vigorous fermentation and helps the pure-yeast cultures to overcome spoilage organisms. Approximately 7 pounds per 1,000 gallons of must is satisfactory.

For the best results, control of temperature during fermentation is necessary. In fermenting wines, it is preferable to keep the temperature between 70° and 75° F. It is sometimes advantageous to start the fermentation at about 80° then cool quickly to 70° and maintain this temperature throughout the remainder of the fermenting period.

Temperature is best controlled by pumping the fermenting liquid through water-cooled or refrigerated coils. This is more efficient than coils immersed in the fermenting vats. The addition of ice directly to the vat is not recommended, owing to the dilution and uneven cooling.

Fermentation may be carried out in redwood or cypress tanks, which are cheaper than glass-lined or stainless-steel equipment although not so sanitary. Owing to the porosity of the wood, cypress tanks must be coated with special pitch. Caution should be exercised against souring of the fermenting tanks. After being emptied they should be thoroughly flushed with water, and then, if they are to stand unused, filled with water containing 50 parts per million of chlorine. A check on the chlorine content should be made from time to time and any deficiency supplied. Before being used again, the tanks should be flushed with clean water.

A Brix hydrometer reading on the juice should be taken every day, and when the reading is 1° or less, fermentation is complete. This usually requires about 10 or 11 days. The wine is then skimmed and siphoned from the sludge of yeast. When diluted, this sludge may be used for the production of brandy. A filter aid (such as standard Filter-cel, standard Supercel, or Dicalite) is added in amounts of 1 to 2 percent, based on the weight of the wine being filtered. The wine is then filtered through an aluminum plate-and-frame press. The filtered wine will be slightly milky in appearance, but this is of no importance, as clarification will proceed with aging, and the wine will be polished before bottling. It is a good plan to remove the yeast sludge as soon as fermentation is complete, thus avoiding off-flavors.

Grapefruit wine is often somewhat bitter, and in some instances, especially if immature fruit has been used, the bitterness may be so intense as to make the wine unpalatable. The bitter taste may be attenuated by treatment with activated charcoal (deflavoring type) at the rate of 4 gm. per liter (one-half ounce per gallon) at 131° F. with rapid agitation for 30 minutes. To prevent loss of alcohol, treatment should be carried out in a covered container. After treatment, the wine is filtered, a filter aid being used as described above.

The wine is stored either in regular aging vats, or, if production is on a small scale, in oak barrels that have been steamed for 3 hours. Optimum storage temperature is from 60° to 65° F.

Fortified Citrus Wines

Fortified citrus wines are made by increasing the alcoholic content to 18 to 24 percent by the addition of spirits or brandy, the preparation of which is explained below. Cane or beet sugar or concentrated must may be used for sweetening. The spirit or brandy used must be made from the same variety of citrus fruit as the wine to which it is added. Federal regulations do not permit the use of grape or other fruit brandies in fortifying citrus wines or the use of orange brandy in fortifying grapefruit or tangerine wine, or vice versa.

Two types of fortified wines may be made: A dry sherry type, made by increasing the alcohol to 18 percent and adjusting the sugar to 7 gm. per 100 cc.; and a sweeter type. which is made by increasing the alcoholic content to 20 percent and adjusting the sugar to 10 gm. per 100 cc. by adding 7 gm. of sucrose and 3 gm. of corn sugar per 100 cc.

Fortified wines are held in wood at a temperature of 125° to 130° F. for 90 to 120 days. during which time the product darkens to nearly the color of sherry.

After aging, which usually requires from 7 to 15 months at 80° F., the wine may be bottled. Before being bottled it must again be filtered. This is accomplished by means of a filter press. closely packed asbestos or paper pulp being used as a filtering medium. Germproof filtration. which removes yeast and bacteria. is often practiced. and if properly carried out will greatly aid in controlling spoilage. After bottling. the wine must be allowed to age still further, or to become bottle ripe.

Brandies

Under the present regulations of the Bureau of Internal Revenue, it is permissible to add sugar not to exceed 11 percent by weight to material intended for making brandy.

Pure cultures of yeast are utilized in making spirits and brandy, in the same manner as in making wine. The temperature of fermentation. however, may be somewhat higher than for wines. namely. around 75° F., without harming the product. High fermentation temperatures (about 85°) are injurious to the finished brandy as they cause the development of excessive amounts of aldehydes and other products. giving it off-flavors.

Upon completion of fermentation. the wine is racked from the yeast sludge and distilled in a beer still provided with a column. dephlegmator, and condenser. The still should be adjusted so that the distillate comes over at 164 proof for spirits and 150 proof for brandy.

For brandy, the 150-proof spirits are cut with distilled water to 101 proof, and then aged in either white oak or charred barrels. The latter give the product a slightly whisky flavor, but appear to age it more rapidly. Old whisky barrels from which most of the char has been removed are satisfactory. Sherry casks are also used for storing brandy.

CORDIALS

Various cordials or liqueurs can be prepared with citrus spirits and citrus and other essential oils. These preparations are not aged in wood, but in glass, the packages being well filled. Mixing is done in glass or enamelware. Any formula may be used, citrus spirits being substituted for the usual commercial spirits.

ESSENTIAL OILS

For years the essential oils of lemon, orange, and lime have been staple products on the world's markets, the production of lemon and orange oils being largely confined to the Island of Sicily, in the Mediterranean Sea (*11*). Some orange oil and most of the world's supply of bergamot oil came from Calabria, on the adjacent Italian coast. The chief center for the production of lime oil has been the West Indies.

More recently, California and Florida have been competing in this trade, producing lemon, orange, and grapefruit oils. French Guinea has been exporting orange oil (*59*). At first, in Italy and Sicily, these oils were expressed by hand or hand-operated machines, but at present the greater part is expressed by power machines. In many cases the machines recover less oil than the hand methods, and the quality of the product is not so good. The cost of hand labor, however, is now prohibitive in most places where the oils are produced. The hand method, also known as the sponge method, which is still used to some extent in Sicily, produces as high as 8 to 10 pounds of oil per ton of fresh fruit. Many of the devices now used in this country express less than half this amount. Whenever, in extracting the oil, water or juice is emulsified with it, the quality of the product is different from that extracted without such contamination.

Most of the oil produced in this country is made by passing the cut fruit through fluted or corrugated rolls, or other types of presses, in such a way that both the juice and the oil are extracted (fig. 14). The two are then separated by centrifuging. Other devices handle the peel alone, pressing it between corrugated rolls. Still others grind or abrade the peel, and express the oil by pressure. Practically all these machines have been devised by operators of juice plants, and few are for sale.

There is also a market for the distilled oil from some citrus fruits, distilled lime oil being the leading commodity in this line. Distilled orange and lemon oils have received considerable attention at times. The demand in this country fluctuates with the price of the cold-pressed oils, but in Europe there seems to be a steady demand for both. Both vacuum and direct steam distillation are used in the production of distilled oils, the yields being very much higher than those obtained by methods using pressure.

The terpeneless or so-called concentrated oils are produced by fractional solution in alcohol or by fractional distillation of the cold-pressed oils (*8*). The operation is carried out under high vacuum by distilling off the terpenes, which have a lower boiling point than the oxygenated constituents. The latter give flavor and aroma to these oils, the terpenes having only minor flavoring value.

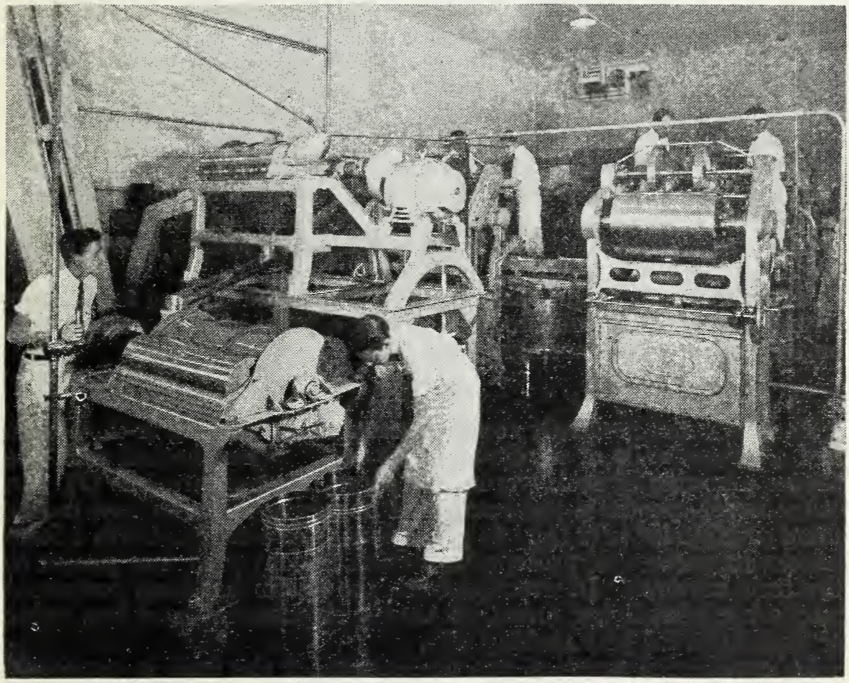

FIGURE 14.—Oil and juice extraction combined.

GLUCOSIDES

Two well-known glucosides are found in citrus fruits. Hesperidin occurs in the rind and membranes of oranges, tangerines, and similar fruits, while naringin is found in all parts of the grapefruit tree, even in the unopened buds.

Hesperidin is a tasteless, white, crystalline compound. It is familiar to growers of citrus as the white material that usually appears in the segment walls of oranges within a short time after they are frozen. Naringin is an intensely bitter, white, crystalline solid.

Neither glucoside has been found of value medicinally (*90*). The fact that naringin is bitter is often advanced as proof of its therapeutic qualities, but up to the present, such claims have not been substantiated by scientific investigation. It has been used to impart a bitter taste to grapefruit beverages, but such use is very limited.

Both substances are easily extracted from the fruits in which they occur (*67*). Hesperidin is soluble in dilute alkali, from which it may be precipitated by passing carbon dioxide through the solution. It is purified by dissolving it in dilute alkali and precipitating it with acetic acid, or better, with carbon dioxide. The precipitated crystals should be allowed to remain in the menstruum for some time in order to build up. The crystals can finally be washed with small quantities of alcohol and ether, and dried at 212° F. This material precipitates from orange-juice concentrates, and the crude product is often found in the tanks and pipe lines of orange-byproduct factories. The melting point of the pure product is 394°.

As naringin is soluble in hot water, an extraction of the ground residue of grapefruit canning plants would yield an abundant supply. Any system of countercurrent extraction can be used. The extracts can be evaporated in the air or under vacuum, and placed in a cool place to crystallize after the solution is seeded with a few crystals of pure naringin. The crude crystals are dissolved in hot water and allowed to recrystallize. The air-dried crystals melt at 183° F. and decompose slightly over 212°. On cooling they form a brown glossy mass.

Rhamnose may be prepared from naringin by refluxing for 2 hours with 3.7 percent of sulfuric acid, giving a yield of 20 percent based on the weight of the naringin used (*72*).

PECTIN

Pectin is an exceedingly complex compound occurring in the albedo and segment walls of all citrus fruits (*81*). When heated with the proper amounts of acid, water, and sugar, the mixture jells (*7*). In other words, pectin is the compound occurring in fruits that makes them suitable for jelly (*4*). In green fruit, this compound is in a form known as pectose or protopectin, which is converted into pectin as the fruit matures. In overripe fruit, the pectin has been converted into other nonjellying forms, so that such material is of less value or even unfit for jelly making (*57*).

In commercial practice, the protopectin of the fruit is converted into pectin by the action of hot acidulated water, in which pectin is soluble (*1, 65, 67, 74, 88*). This solution is then treated in various ways to precipitate the pectin (*53*). After being filtered with infusorial earth, it can be evaporated under reduced pressure to a viscous liquid of 25- to 50-percent solids. Sufficient alcohol is then added to bring the strength of the mixture to 65 percent of alcohol by volume. The pectin is precipitated, and the alcohol is removed by decantation. The granular pectin is washed by beating it with fresh alcohol. The thoroughly washed material can be dried at 158° F. (*83, 88*).

Another method used for commercial production consists in precipitating the pectin from solution by the addition of a hydroxide of positive electrical charge. After the enzymes have been inactivated by heat, the peel or residue is extracted with a dilute solution (about 0.25 percent) of sulfur dioxide at 176° to 194° F. After filtering, the solution is made slightly alkaline with ammonia. A metallic salt, such as aluminum sulfate, is then added. This precipitates the colloidal pectin in the presence of the electrolyte. On settling, the clear liquid is drawn off, and the pectin is washed. This separation may also be made by filtering. The precipitate may contain aluminum hydroxide, which can be removed by washing with alcohol acidified with hydrochloric acid. The washings are neutralized and distilled for recovery of the alcohol.

Powdered pectin should be standardized as to its jellying strength (*75*). The standard used is the amount of sugar 1 pound of the product will cause to jell under proper dilution and acidity. Thus, 1 pound of grade 100 pectin will jell 100 pounds of sugar in solution in the fruit extract. The sugar is estimated on the amount in the fruit plus that added in making the jelly.

Some pectin sold is in liquid form. The pectin in these solutions is equivalent to grade 5 or less. There is also a product on the market that consists of ground citrus peel from which the coloring matter and oil have been removed by extraction with alcohol. Pectin is also produced from the pomace waste of cider and vinegar plants.

Many patents have been issued on the preparation of pectin. The list of Literature Cited includes references to some of these (*25, 34, 35, 42, 49, 51, 52, 69, 80, 85*), together with references to the literature on this subject (*57, 76*).

CANDIED CITRUS PEEL

Candied grapefruit peel makes an excellent center for chocolate candies and also serves as a substitute for citron in baking (*16*). Candied orange peel, while less like a confection, has sufficient merit to make it satisfactory for many purposes (*10*). Large thick-skinned fruit, free from blemishes, yields the best product. The candied peel, ground or shredded, may be mixed with icings for cakes or with dough for cookies; also it may replace shredded coconut in home-made candies and fresh orange peel in marmalade. Many firms now use similar products instead of citron in making mincemeat (*27*).

GRAPEFRUIT PEEL

Wash the fruit and remove the peel, leaving as little as possible of the albedo attached to the fruit. The peel can be more readily detached if the fruit is dipped into boiling water for a few minutes. If peel from fruit from which the juice has been pressed is to be used, the segment walls can be cleaned away with a knife. Not all the peel from this class of material can be saved, but usually enough is recovered to make it pay. Cut the peel into strips 2 inches long by one-fourth of an inch wide, or ½-inch disks or squares, or other shapes.

There are two methods of cooking the peel. Water alone may be used, or a preliminary treatment with limewater may be given. Under certain conditions the finished product has a slightly tough layer at the outer surface of the original peel. This toughness can be avoided by using limewater, although as a rule the use of water alone gives almost as good results. Only clear limewater should be used for this purpose, never milk of lime. Limewater contains less than 0.2 percent of lime in solution and will not injure the peel.

Place the prepared peel in a kettle and cover it either with a mixture consisting of 2 parts of water and 1 part of clear limewater, or with water alone. Cover and boil for half an hour. Pour off the liquid. Again cover with water, boil for half an hour, pour off the liquid, and add fresh water. Do not use limewater after the first cooking. Repeat this procedure until a piece of the peel when removed and cooled has about the bitter taste desired in the finished product. The final product will be a little less bitter than the peel at this stage, as some of the bitterness disappears on further cooking. Usually three treatments are sufficient when a rather bitter flavor is desired. Five or six treatments produce a mild-flavored peel; more than that number give a product without much grapefruit flavor. When the desired flavor is reached, pour off the water and drain the peel. The excess of water can be removed by gentle pressure.

Prepare a sirup, using equal parts of cane or beet sugar and water, with 0.05 percent of citric acid, and cover the peel with it. Boil very slowly for an hour or so, and allow the peel to remain in the sirup overnight, or longer if convenient. Finally boil again until the sirup becomes thick, stopping at the usual stage for jelly making; that is, when the sirup flakes or sheets from the spoon, or the temperature on a candy thermometer is about 219° F. The peel is satisfactory even if cooking is stopped before it reaches this point; overcooking makes it hard. Drain the hot sirup from the peel as completely as possible, shaking repeatedly to remove the last drops. Roll in powdered sugar, separating any pieces that stick together. Cool, and allow to remain in the air to dry for several days.

Place the dry candied peel in airtight jars or cans, where it will keep for months.

ORANGE PEEL

With slight modifications, the method used for grapefruit peel can be used for orange peel.

Wash the fruit, remove the peel, and cut it into thin strips, about an inch long. Cover with water and boil for an hour, being careful to renew the water so that all the peel remains covered. Pour off the water and repeat this operation at least once. The peel should be tender before the treatment with boiling water is stopped. As this peel lacks the bitter taste of grapefruit peel, two treatments are usually enough.

After the water from the last treatment has been drained off, cover the tender peel with a 50-percent sugar sirup, and cook it as directed for grapefruit peel. After the sirup has been drained off, roll the peel in powdered sugar and expose it to the air until dry.

Store the dry peel in airtight cans or jars.

CITRON

Citron should be picked while still green but after it has attained its full growth. For preserving, it is perforated over its entire surface at points about an inch apart, and cut in halves (*44*). The small amount of pulp and seeds is allowed to remain, as they are more easily removed after the brining process. The halves are placed in wooden vats or crocks and covered with a 3.5-percent salt solution, being held under the solution by suitable covers and weights (*21*). Fermentation takes place, shown by the bubbling of carbon dioxide in the salt solution, the amount depending on the temperature of the room. After about 15 days, the brine is replaced by fresh brine and generally very little more fermentation occurs, although the citron becomes translucent throughout in a few days. If 9 percent of salt and 0.15 percent of sodium or 0.17 percent of potassium metabisulfite are then added, it can be kept in the brine solution for several months without molding, the length of time here also depending on the temperature. The 0.17 percent of potassium metabisulfite produces 0.10 percent of sulfur dioxide, which prevents mold, and does not affect the green color. The firmness and translucence produced by the brining process remain after the preserving or siruping process has been completed.

After the brining process, the pulp is removed and the peel is boiled gently for 30 minutes in fresh water, followed by another boiling for 20 minutes, or until a needle will easily penetrate it.

Two different types of sirup can be used to candy the peel. One contains only cane or beet sugar, but enough citric acid is always used to invert part of the sugar so that it will not crystallize in the peel when stored. Citric acid, 0.05 percent, is added to the sirup at the beginning, and twice during the processing 0.02 percent more is added. The other type of sirup contains either 40 percent of glucose or corn sugar or one of the commercial invert sugars. The remaining 60 percent consists of cane or beet sugar. Peel made with either type of sirup is of the highest grade, retaining the desired firm texture, green color, and translucent appearance.

The siruping process is carried out as follows: Heat a 20° Brix solution of either type of sirup to boiling. Add the half peels and set aside overnight. Then remove the citron and add enough sugar to the sirup to raise it to 30°. Heat to boiling, add the citron, and set aside for 2 days. Continue this process, raising the Brix reading 10° and setting aside for 1 day longer each time, until 60° is reached. The next time raise to 75° but allow the peel to remain in the sirup while heating to the boiling point. Set aside for 1 day longer than at 60°. Then heat to boiling, remove the peel from the sirup, and dip it quickly twice into hot water. This removes the excess sirup. Place in front of a fan for about 12 hours or until the citron is comparatively dry.

Citron Pieces

A delicious confection can be made from citron by slicing the brined peel, boiling it twice in water until tender, and then candying. The slices should be about one-eighth of an inch thick. The candying can be hastened by raising the Brix reading 20° each time instead of 10°. Half-inch cubes, disks, or other forms can be produced in a similar manner. The final product is dipped quickly into hot water and dried with a fan. The pieces or slices may be rolled in powdered sugar, if an especially dry and sugary confection is desired.

MARMALADES

There are almost as many ways to make marmalade as there are manufacturers of the product. The following directions, if carefully followed, give excellent products.

Clear Orange Marmalade

Wash and peel the fruit. Separate one-fourth to one-half the peel, choosing that which is free from blemishes. Cut this peel into very thin slices, cover with water, and cook until tender, changing the water at least twice during the cooking (*24*). When large quantities are being prepared, the method used for candied peel can be employed, stopping the process after the final cooking but leaving the peel in the sirup until ready for use.

Cut the peeled fruit into small pieces and put into a kettle with twice its weight of water. If a highly colored, heavily jelled product is desired, part of the discarded peel can be cooked with the pulp. Cover the kettle and cook until the pieces are thoroughly disintegrated. At this point make tests for acidity and pectin. From 0.5 to 0.7 percent of acid and about 0.5 percent of pectin should be present. Any deficiency in either should be made up by the addition of lemon juice for acidity and peel for pectin. Filter the cooked pulp by pressing in a coarse filter cloth. Stir into the filtrate 5 pounds of thoroughly washed kieselguhr for each 100 gallons of liquid. Let this settle and then filter through cloth. A rack-and-plate press can be used for this operation.

To the clear stock add 1 pound of sugar for each pound of fruit originally taken, including the cooked peel, if peel is added. Boil as rapidly as possible until the jelly stage is reached, which is usually about 220° F. It is best not to depend entirely on the boiling point, however, as heavy pectin jellies set with a lower sugar content than those containing less pectin. If candied peel is used, it is removed from the final sirup and added to the marmalade just before the batch is poured into the containers. In fact, the peel can be placed in the containers and the finished jelly poured on it.

Pour the marmalade into hot glasses. If the peel separates, stir before the jelly sets. Let stand until cool, and then cover with paraffin.

Orange Marmalade (Rapid Method)

Select fruit of medium maturity and wash it thoroughly, carefully removing blemish spots.

Remove the peel from about one-third of the oranges, slice it very thin, cover with water, and boil, with three changes of water, until tender, usually about 30 minutes. The peel may be added to the jelly stock in this condition, or it may be candied by the methods previously given. In the latter case the process is stopped after the final cooking, but the peel is left in the sirup until ready for use, when the sirup is drained off and the peel is added to the marmalade.

Grind the whole oranges, peeled and unpeeled, in a meat grinder and boil gently for an hour with only 1½ volumes of water. Press the cooked pulp and clarify the extract with kieselguhr, adding enough clarified lemon juice to bring the acidity to 1 percent. For commercial production, it would be advisable to determine the pectin roughly by precipitation with alcohol, or it might be better to make a trial batch of jelly. using equal parts of extract and sugar and boiling for 10 minutes. The extract should contain about 0.6 percent of pectin.

Boil, for 10 minutes only, equal parts of sugar and extract and one-third part of candied peel or one-fifth part of uncandied peel, skimming thoroughly during the boiling.

As the jellying quality depends to a great extent on the maturity of the fruit, slight variation in the proportions given may be necessary, but the short periods of boiling, both in extracting and in making the jelly, should be maintained.

The marmalade can usually be poured into glasses immediately. If the peel either rises or settles, allow the temperature to drop to about 156° F. before pouring. Cool and seal as directed on page 36.

Sweet Orange Marmalade

Wash and peel the fruit. Weigh the peel and discard one-fourth of it, noting the weight of the pulp plus the remaining peel.

Place the peel in water, boil for 5 minutes, and pour off the water. Cover the peel again with water and allow it to simmer over the fire until tender. Then pour off the water and add cold water to harden the peel. Next cut the peel into as thin slices as possible.

Place the peeled oranges in a kettle, add twice their weight of water, and boil until the pulp has disintegrated. Strain through a muslin or cheesecloth bag.

Add the shredded peel to the juice and stir in 1½ pounds of sugar for each pound of the original peeled fruit plus the shredded peel. Boil until the jellying point is reached.

Pour the finished product into the glasses or jars and seal as directed for clear orange marmalade (p. 36).

This method may also be used for grapefruit marmalade.

Bitter Orange Marmalade

Wash and peel the fruit. Weigh the peel and discard one-fourth of it. Cut the peel into as thin slices as possible; place it in a kettle with four times its weight of water; boil for 10 minutes, and drain off the water. Repeat this process three times.

After the peel has been removed, weigh the fruit and cut it into small pieces. Place it in a kettle and for each pound add 2 pounds of water. Boil until it is thoroughly disintegrated. Pour the mass into a flannel jelly bag and press until no more juice can be extracted. Drain this juice again through a clean flannel jelly bag without pressing, or treat it with kieselguhr as directed on page 36.

Pour the juice into the kettle, add the sliced peel, and bring to a boil. Add 1½ pounds of sugar for each pound of fruit and continue the boiling until the jelly stage is reached, as indicated by flaking or sheeting from a spoon (*18*).

Pour the finished product into glasses or jars, and seal as directed on page 36.

Marmalade Stock

Marmalade stock consists of fruit processed to a point where the addition of an equal weight of sugar, and heating, will produce marmalade. The advantage of preparing marmalade stock instead of the finished marmalade is that weight and bulk are less, and consequently the costs for containers and shipping are less. Manufacturers in distributing centers can complete the processing and pack the marmalade for sale, or the stock can be sold direct to the housewife, to be converted into marmalade with little time or labor.

Grapefruit Marmalade

Marsh Seedless grapefruit is the most desirable variety for marmalade as it contains the fewest seeds. The fruit is thoroughly cleaned, and blemished peel is removed. Stem and blossom ends are cut off and discarded, and the fruit is then sliced at right angles to the axis. The slices are covered with just sufficient water to permit cooking, sufficient lemon or lime juice is added to adjust the citric acid content to 1.5 percent, and the mixture is allowed to boil slowly until tender. This takes approximately 20 to 30 minutes, depending on the ripeness of the fruit and the size of the batch. Local overheating should be avoided by careful stirring. The product may be filled hot into sterilized tin or glass containers and sealed immediately. It keeps indefinitely as a marmalade stock.

In making the finished marmalade, heat the stock to boiling, add an equal weight of sugar and boil until the jelly stage is reached. Either fresh or preserved stock produces a bright-yellow translucent marmalade of fine appearance. It has a pronounced grapefruit flavor and a bitterness about equal to that of commercial bitter, or Seville, orange marmalade.

Shredded-Grapefruit-Peel Marmalade

Shredded-grapefruit-peel marmalade is considerably more expensive to make than other kinds of marmalade, and only about one-half as much is obtained from the fruit. It is not bitter, however, and it has an attractive appearance and flavor. Marsh or Duncan grapefruit is equally suitable for making this marmalade. The fruit is cleaned, and any blemished peel is removed. Each individual fruit is then clamped in a small machine that resembles a turning lathe, with concave disks clasping the stem and blossom ends of the fruit. The peel is scored from stem to blossom end in 3 to 5 places, and the fruit is then rotated at a speed of from 150 to 250 revolutions per minute. A shredding tool, consisting of a curved piece of steel with ⅛-inch diagonal perforation, is rapidly moved from edge to edge of the exposed surface of the rotating fruit. The shreds are cooked until tender in 0.5 percent bicarbonate of soda solution, and thoroughly rinsed.

The peeled fruit is cut in halves, and the juice is reamed, screened, and strained. The acidity is adjusted to 1.5 percent by adding lemon or lime juice, and 1 pound of grade 100 pectin is added for each 100 pounds of juice. The mixture is boiled until all pectin is dissolved. The shredded cooked peel is then added, and the product is heated until it boils vigorously. It is then filled into sterilized tin or glass containers, and sealed. It keeps indefinitely.

In manufacturing the stock into marmalade, it is heated to boiling, an equal weight of sugar is added, and boiling is continued until the jelly stage is reached. This produces a bright-yellow marmalade of attractive appearance and pleasing flavor with no appreciable bitterness.

CALAMONDIN MARMALADE

Calamondin trees are planted chiefly as ornamentals. The brightly colored fruit is about the size of a lime and the color and texture of a tangerine, and contains about 4.5 percent of citric acid. Although the skin is too thin for successful shipment of the fresh fruit, the brilliant color and delicate texture and flavor make it particularly suitable for the preparation of fancy marmalade.

In preparing marmalade, the fruit is washed and peeled. The peel may be cut into fancy shapes with special dies if desired, or it may be sliced in thin shreds. The peel contains virtually no albedo, so the shreds are thin and brightly colored. The shredded peel is cooked until tender in water containing 0.5 percent of bicarbonate of soda, drained, and thoroughly rinsed. The peeled fruit is crushed, mixed with one and one-half times its weight of water (or orange or grapefruit juice), and boiled for 30 minutes, after which it is strained under pressure and re-strained to insure a sparkling marmalade. It is necessary to add some pectin, as the calamondin contains very little. Approximately one-half pound of grade 100 pectin per 100 pounds of stock is satisfactory, although this must be varied with the condition of the fruit. The strained juice is heated to boiling, and the cooked peel is added, after which the product may be filled hot into sterilized glass or tin containers for storage or shipment and subsequent use.

In preparing marmalade from this stock, it is heated to boiling, an equal weight of sugar is added, and boiling is continued until the jelly stage is reached.

JELLIES

BITTER ORANGE JELLY

Prepare the juice as directed for bitter orange marmalade. Add 1 pound of sugar for each pound of fruit. Boil this until it reaches the jellying point. No peel is used in the jelly.

GRAPEFRUIT JELLY

Grapefruit jelly is made in the same way as bitter orange jelly, except that three-fourths of a pound of sugar is added for each pound of fruit.

ORANGE BUTTER

The following recipe makes a product similar in many ways to apple butter. It spreads more easily than most marmalades or jellies, and is not so sweet. It is especially popular with children.

Wash the fruit, carefully removing the stems, seeds, and blemish spots. Cut into slices or small pieces, cover with water and cook until the peel is tender, which usually takes 2 or 3 hours.

Add sugar, either cane, beet, or corn, using half a pound for each pound of fruit. Cook the mixture rapidly, with constant stirring, until a small sample when cooled has the desired consistency. It is best to cook beyond the jellying point. Cooking to 225° to 227° F. has given the best results in the laboratory. As soon as it is cool enough, pass it through a food grinder until all lumps are reduced.

A satisfactory orange-pineapple butter may be made by adding 15 percent of pineapple pulp to this material.

DISPOSAL OF WASTE

Disposal of waste resulting from the operation of citrus-canning plants or byproduct factories constitutes a problem of no little importance. This is particularly true when the plant is located in a closely settled neighborhood, a large town, or a city. If dumped on open ground, the waste is soon covered with swarms of vinegar flies, becomes malodorous, and is likely to be condemned by the local health authorities. In some cases this method of disposal has resulted in damage suits for contaminated wells and sick livestock. In only a few favorable cases can the fresh material be given away for cattle or hog feed (*73*). Therefore, there is nearly always a definite cost for properly disposing of such residues.

This waste has some value as both feed and fertilizer (*46*, *47*, *54*), although when used as fertilizer on citrus groves, there is danger of spreading pests if it contains unheated peel. Its chief value as fertilizer lies in the organic matter or humus that it adds to the soil. As a rule, it contains less than 1 percent of nitrogen and less than 0.5 percent of mineral matter, more than half of which is potash and phosphoric acid. The amount that can be satisfactorily used is limited. The character of the soil and the method of application are the factors that have to be considered. Only the amount that can be thoroughly disked in should be spread. Burying in deep furrows or trenches is an effective method of application and reduces the likelihood of pest contamination to a minimum.

Table 2 shows that as feed for cattle or poultry the nutritional value of citrus waste is similar to that of beet pulp or barley, except for its lower protein content.

TABLE 2.—*Composition of citrus waste, beet pulp, and barley*

[On moisture-free basis]

Material	Crude protein	Crude fiber	Ether extract [1]	Nitrogen-free extract	Ash
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Grapefruit-canning waste	5.3	13.0	1.2	75.9	4.6
Lemon residues	9.87	16.7		68.5	4.9
Orange residues	5.8	10.0	2.4	77.7	4.0
Beet pulp	9.4	22.2	1.4	63.5	3.6
Barley	11.7	3.9	2.9	78.3	3.1

[1] In citrus waste, the ether extract is probably of little value for feeding.

As competitive products are very low priced, the cost of drying citrus residues must be as low as possible, consistent with quality. The moisture content of the wet material often determines the drying method. If a direct-fired rotating drier is to be used, the residue must be sufficiently dry not to stick to the sides of the drier. If the residue sticks, the transfer of heat is greatly retarded, and the final product may contain charred pieces.

To avoid this difficulty and to increase the capacity of the driers, the moisture content is reduced before drying by running the waste peel through a press. Many operators use a patented process in which the ground mass is treated with lime before it is pressed. This treatment coagulates the gummy materials and facilitates the pressing. Moderate pressing will reduce the moisture content of the waste peel from 88 or 90 to 80 percent. It should be kept in mind, however, that the liquid pressed from the peel has a definite feeding value. If the waste has been purchased and money spent in getting it to the drier, this investment is lost so far as the discarded liquid is concerned. A further problem is created by its disposal. It is too high in organic matter to run into sewage-disposal plants, and it cannot be run into small streams or lakes without danger to the fish. The material is not poisonous itself, but uses up the dissolved oxygen in the water, which is needed by the fish.

Each operator should study his own costs and determine just how much liquid he can profitably press from his waste peel.

If the residues contain sufficient moisture to render the whole mass fluid, it can be ground and dried on a rotary drum drier. The quality of the product thus prepared is usually very fine, but the cost of production is also higher than where a direct-fired drier is used. Experiments in feeding dried citrus pulp indicate that it is an acceptable substitute for either beet pulp or barley.

The dried waste from orange-juice canneries is sold under the designation "orange meal." It consists of the ground and dried peel and inner segment walls. The oil or a part of it has been removed from the greater part of the peel. The drying process tends to evaporate the peel oil, which is more or less objectionable in the finished product.

The dry distillation of citrus waste yields methanol, acetone, acetic acid, and tar. The quantity of these products is not sufficient, however, to make their recovery profitable at present market prices (*63*).

UTILIZATION OF THE SEED

Where a sufficient amount of waste containing seeds is accumulated in one place, it may be possible to separate the seeds by screening. They can then be dried and used for the production of seed oil or for other purposes. Grapefruit-seed oil has been prepared commercially in Florida. The crude oil has an extremely bitter taste, but may be refined to yield a bland product (*62*). Lime-seed oil has been prepared in the West Indies (*19*).

SUMMARY

A brief review of the status of the citrus-products industry, together with a statement of the composition of the common citrus fruits, is given, also a description in some detail of the commercial methods of preparation of citrus products. It may seem that in some cases, for example, the production of the essential oils, the text is inadequate. This is because most of the devices now in use are the result of long study and experimentation on the part of the owners, and it would be manifestly improper to divulge their trade secrets.

Methods for canning juice and segments, for producing beverage material, wines and brandies, vinegar, pectin, marmalades and marmalade stock, jellies, candied peel, and essential oils are given. There is also a brief statement on the disposal of waste.

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